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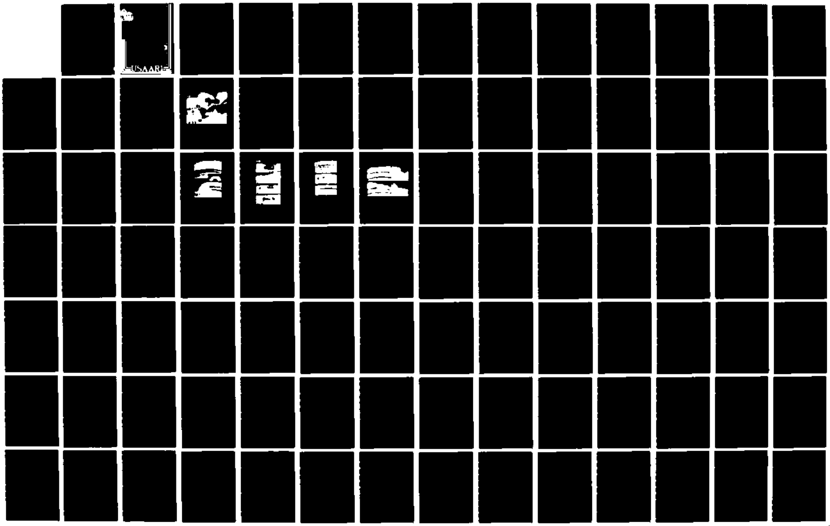

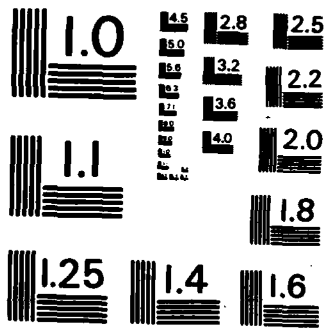

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USAARL REPORT NO. 85-3

THE EFFECT OF IMPULSE INTENSITY AND THE NUMBER OF IMPULSES ON HEARING AND COCHLEAR PATHOLOGY IN THE CHINCHILLA

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June 1985

USAARL

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ABSTRACT:
Forty-one chinchillas, divided into seven groups, were exposed to 1, 10, or 100 noise impulses having peak intensities of 131 dB, 135 dB, 139 dB or 147 dB. Hearing thresholds were measured in each animal prior to exposure using an avoidance conditioning procedure. Threshold shifts were monitored at regular intervals over a 30-day post-exposure period. A surface preparation of the cochlear sensory epithelia was performed approximately 90 days after exposure. There was generally an orderly relation between the amount of permanent threshold shift and the severity of exposure, and a general agreement between averaged histological data and the audiometric data. Detailed relations between temporary and permanent threshold shift, cochlear pathology, and exposure variables are discussed, as are the implications of these data to the development of exposure criteria. All tabulated individual animal data, averaged group data, and individual cochleograms are presented in Appendixes A through D.

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INTRODUCTION

Exposure to excessive levels of noise is the principle cause of deafness in the adult population and is a problem which is particularly acute in many industrial and military settings. While we have made important advances over the last decade in understanding the problem of noise-induced hearing loss, especially the effects of continuous noise, there is still a comparative paucity of data on the effects of impulse noise or blast waves on hearing.

There currently exists a number of criteria for limiting exposure to impulse noise (CHABA, 1968; MIL-STD-1474(B); Coles, et al., 1968; Pfander, et al., 1980, and Smoorenburg, 1982). While these criteria all use peak pressure as the fundamental indicator of intensity, they differ in their measures of impulse duration and their rules for trading intensity and allowable number of impulses. The primary reason that these differences exist is the shortage of reliable parametric data on which to base the criteria. These exposure criteria are based on either a very limited experimental data base or upon a variety of demographic studies with all their attendant difficulties. This paper describes a parametric study of the effects of a varying intensity and number of impulses on hearing loss and injury to the sensory organ for hearing.

The trading relationship between intensity and the number of impulses is an important one for the establishment of damage risk criteria. For a number of years, the trading relationship that has been in use in the United States and has been incorporated in a number of criteria (CHABA, 1968; MIL-STD-1474B) is the 5 dB adjustment in peak pressure for a tenfold change in the number of impulses (CHABA, 1968). This guiding principle represents only the "educated guess" of Coles, et al., 1968. Quoting from their paper: "...where exposure is to occasional single impulses only, it seems reasonable to raise the limits somewhat, and an estimate of 10 dB has been agreed upon for this. The exact allowances for different numbers of impulses have not been defined, since there are obviously an infinite number of variations in the pattern and amount of noise exposure." The major alternative trading relationship for intensity and number of impulses is based on an equal energy concept (Pfander, et al., 1980; Smoorenburg, 1982). This approach is related to the "Equal Energy Hypothesis" (EEH) (Burns and Robinson, 1970; Eldred et al., 1955; and Martin, 1976). Equal energy implies a 10 dB adjustment in peak pressure for a tenfold change in number of impulses.

The experiments described in this report provide data on the trading relationship between impulse intensity and the number of impulses. The findings are limited because the impulse pressure-time history and the inter-pulse interval were not varied during this study. Although the research that is described in this report was performed using an animal model, the general relations that were found may be scaled to human exposures eventually. An extrapolation scheme can be developed once sufficient data are obtained on different species, including primates.

METHODS AND PROCEDURES

The experiments that are described in this report follow a relatively straightforward paradigm: Preexposure measures of hearing are obtained on each animal; the animal is exposed to the impulse noise; following exposure, the animal's hearing thresholds are remeasured at various postexposure times; then following a fixed period of recovery, the sensory structures of the cochlea are prepared for histological examination. Such a paradigm allows for correlations to be made among variables, such as (1) the physical exposure conditions, (2) temporary changes in hearing, (3) permanent changes in hearing, and (4) the extent and nature of the cochlear damage.

Subjects: The subjects were monaural chinchillas aged from not less than 12 to approximately 24 months at the start of the study. Each animal was made monaural by surgically destroying the left cochlea, thus deafening each animal in the left ear. The surgery was performed with the animal anesthetized to surgical depth using halothane gas. An incision was made in the skin over the posterior surface of the auditory bulla and a small hole was made in the bone of the bulla to provide access to the cochlea. The cochlea then was destroyed using a small metal probe to break the bone away from each turn of the cochlea (Miller, 1970). The animals were allowed at least one week postoperative recovery time before proceeding with the audiometric training and testing.

Audiometric Apparatus: The audiometric instrumentation has been previously described in detail by Burdick et al., 1978. Briefly, the chinchillas were tested in a double-grilled cage within a 1200 Series Industrial Acoustics Company (IAC)* sound room. Mounted on the cage was a row of photocells to detect the animal's location and an electronic buzzer which was used as a secondary reinforcer. A Fluke* Model 6010A synthesized signal generator, an attenuator, and an amplifier were used to generate and adjust the signal level. The pure tone signals were delivered through an Altec* coaxial loudspeaker. The control, duration, and sequencing of events, as well as recording, were accomplished using a microprocessor. The behavior of the animals was monitored on a closed circuit television.

Training and Threshold Testing Procedures: The procedures for training and testing the animals were similar to those described previously (Burdick, et al., 1978). Briefly, the animals were conditioned to avoid an AC electric shock (1.4 mA nominal level) by crossing from one compartment to the other of the double-grilled cage during a 3.84-s trial interval during which a pulsed, pure-tone signal was presented. Each trial interval consisted of three tone pulses with 720-ms on-times separated by 560-ms off-times. The tone pulse had an exponential rise and decay function with a first time constant of 14 ms. When the avoidance response was made, the signal immediately was terminated. If the subject failed to cross from one compartment to the other during the trial interval, a shock and buzzer were presented simultaneously until the

*See Appendix F

crossing response was made. This resulted in the termination of the shock, buzzer, and signal.

Each group of subjects received training sessions until all subjects scored 95% correct for three successive sessions. During the training sessions, the animals were given one trial at each of the following nine frequencies: 0.125, 0.25, 0.5, 1.0, 1.4, 2.0, 4.0, 5.7, and 8.0 kHz. Later in the experiments, 2.8 kHz was added to the test frequencies. The intensities of the tones varied over a 15 dB range (50-65 dB SPL re: 20 uPa) during all the training sessions. During the first training sessions, trials were presented with an average intertrial interval of 60 s. Then trials were presented for one or more sessions using intertrial intervals of 45, 30, and finally 20 s. Once this was accomplished, all subsequent training and testing was performed using a 20 s intertrial interval. Once the training criterion was obtained, threshold determinations were begun.

A modified method of limits (Burdick, et al., 1978; Miller, 1970) was used to estimate thresholds. On the first trial of a threshold measurement, the signal level was set to 40 dB below the full output (dB) calibration level for the particular test frequency. An additional randomly-set attenuation of up to 10 dB was added to the initial 40 dB for each frequency. The initial signals could thus range from 40-65 dB SPL. A correct response at this first presentation level resulted in a further 20 dB reduction in level for the next trial and so on, until the animal failed to respond.

On the trial following a miss, the level of the signal was increased 10 dB and the threshold was taken as the level halfway between the lowest level that was responded to correctly and the highest level missed. After threshold values began to stabilize, which required from 8-10 complete audiograms, a threshold value was discarded if it differed from the values in Table 1 by 15 dB and a second threshold measurement was taken. The threshold obtained on the second determination always was accepted. A sham trial always followed the last trial of each threshold determination. This was done to obtain an estimate of the rate of "spontaneous responding." These trials were identical to the regular trials except that the synthesizer was set to "zero" frequency and the shock and buzzer were turned off. There was no consequence to the animal for spontaneous responses. Shock was turned off and only the buzzer was used as a secondary reinforcer when the signal level was within 10 dB of the values in Table 1.

Audiograms were taken until the average threshold was within plus or minus 5 dB of the average of the values in Table 1 on the five consecutive sessions. Then audiograms were continued until the day of exposure. The last five audiograms before exposure were averaged across sessions to produce the baseline audiogram for that particular animal. The baseline audiogram for each animal was used as a reference for computing the post-exposure threshold shifts. A complete listing of individual animal thresholds, group average audiograms, and the total averaged preexposure audiograms for all 41 animals is presented in Appendix A.

TABLE 1

REFERENCE NORMAL AUDIOGRAM FOR THE CHINCHILLA BASED UPON THE DATA OF MILLER, 1970 AND BURDICK ET AL. 1978

	Frequency kHz										
	0.125	0.250	0.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0	Mean
Reference Level dB (SPL)	25	10	0	0	0	0	0	0	0	5	4

Exposure Stimuli: Figure 1 shows the pressure-time history and spectrum of the impulse used in these experiments. The spectrum of the impulse is a comparatively broad band spectrum, extending from approximately 0.5 to 3.5 kHz with smooth, regularly spaced peaks throughout this frequency range.

The exposure stimuli were synthesized using a computer-generated rectangular electrical pulse from a digital-to-analogue (D-A) converter. The output of the D-A converter was low-pass filtered at 5.0 kHz by a Rockland* System 886, 8-pole Bessel filter. This signal was then amplified through an Altec amplifier and converted to acoustic impulses by an Altec 290D driver. A 10 cm extension throat with a 4.8 cm diameter opening was bolted to the driver.

Before each exposure, the impulses emitted by the high intensity driver were calibrated. A 1/4-inch condenser microphone (B&K* type 4135) was positioned with the diaphragm at grazing incidence in the center of the opening of the extension throat and 1 mm outside the throat. All levels and spectra were measured with this setup, but with no animal present. The microphone remained in place to record the exposure impulses.

The animal was positioned with the entrance of the ear canal at the center of the driver extension throat. The animal's pinna was taped to a flange on the throat which served to stabilize the positioning of both the ear canal and the pinna. Casual observation indicated that stabilizing the pinna was necessary since some animals would fold the pinna back along the head and possibly close the ear canal. Figure 2 shows the exposure setup with the animal in place.

A total of 41 animals were used in these experiments. They were divided into seven groups, A through G, and exposed to the impulse conditions presented in Table 2. The entire sequence of exposure impulses was recorded on a Nagra* IV-S tape recorder. All impulses were presented at the rate of 1 impulse/3 s.

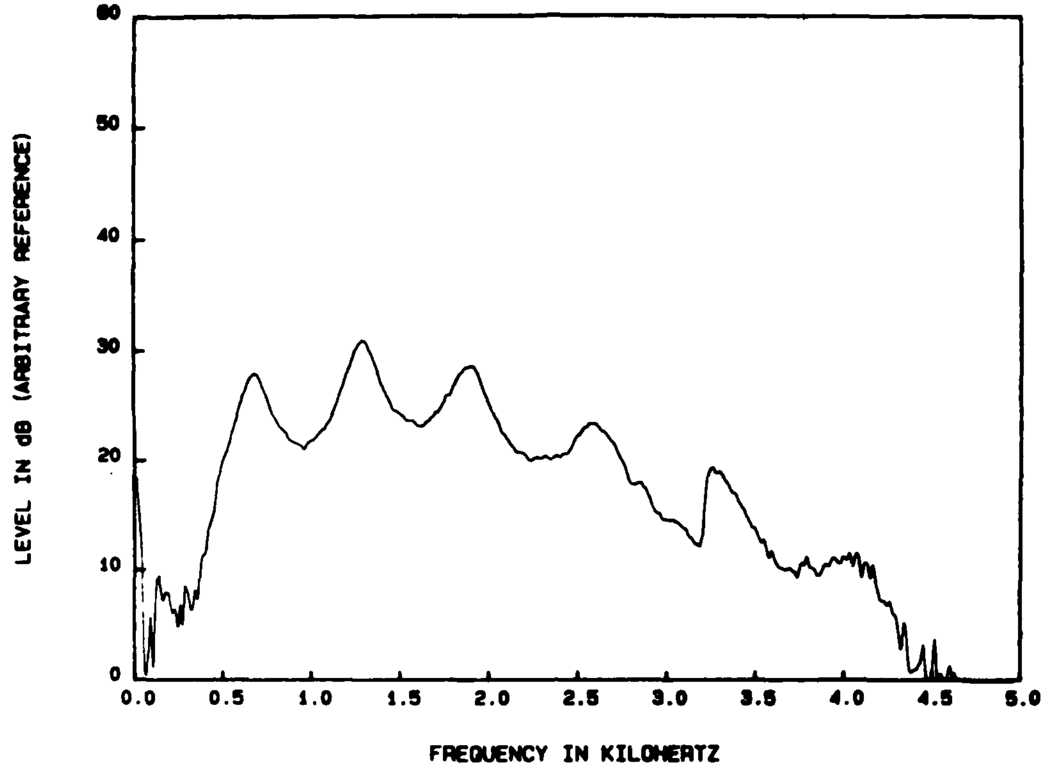

FIGURE 1. The impulse pressure-time wave form (upper) and the frequency spectrum of the impulse (lower).

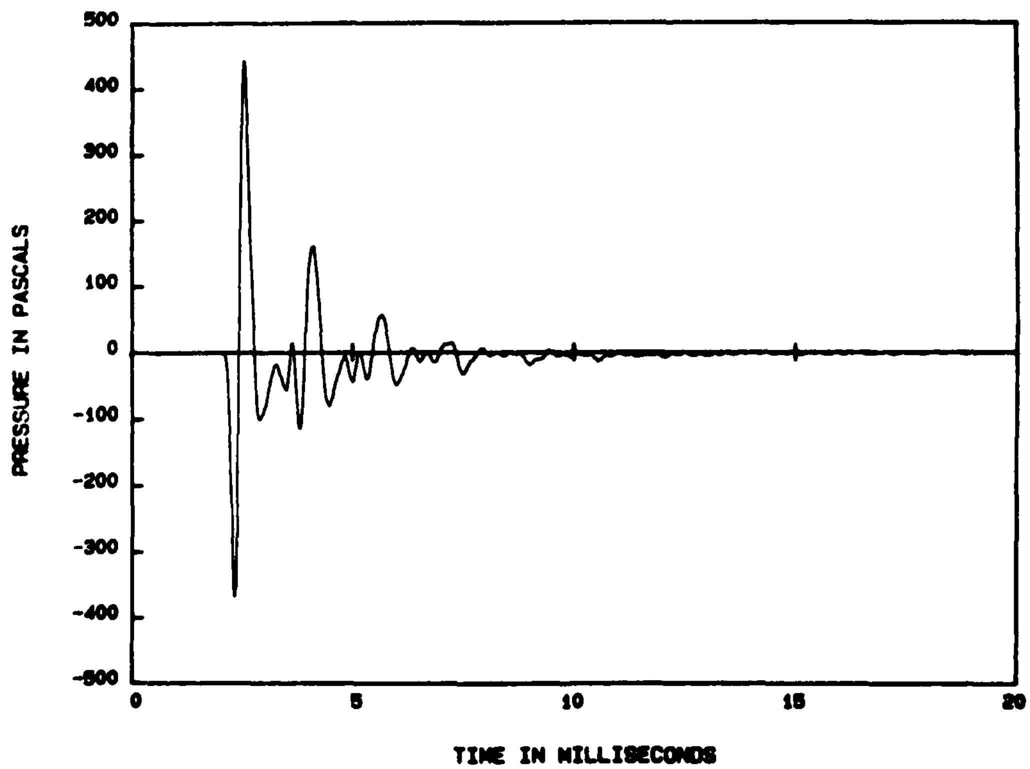

FIGURE 2. An overview of the exposure setup with the chinchilla in place.

TABLE 2

IDENTIFICATION OF THE EXPOSURE CONDITIONS FOR THE SEVEN EXPERIMENTAL GROUPS

Experimental Group	Peak Pressure Level	Number of Impulses	Number of Animals in the Group
A	131 dB	100	5
B	135 dB	100	6
C	139 dB	10	6
D	139 dB	100	6
E	147 dB	1	6
F	147 dB	10	6
G	147 dB	100	6

Recovery Conditions: After an exposure, complete audiograms were obtained starting 2 minutes (referred to as time t=0), 32 minutes, 62 minutes, 92 minutes, 182 minutes, 362 minutes, 24 hours, 48 hours, 6, 9, 13, 16, 20, 23, 27 and 30 days after exposure. Temporary Threshold Shifts (TTS) for each animal were calculated from each postexposure audiogram by subtracting the animal's baseline audiogram. The threshold shifts obtained at 20, 23, 27, and 30 days postexposure for each animal were averaged to produce an estimate of the animal's Permanent Threshold Shift (PTS). The individual animal's TTS data were averaged across all animals constituting a particular group to obtain the group average TTS or PTS. A complete tabulation of individual animal threshold shift data and averaged group data is presented in Appendix B.

Histology: At 88 to 90 days postexposure the animals were anesthetized with halothane and then decapitated. Following decapitation, the two auditory bullae were removed and opened widely. The right stapes was removed and the round window membrane was slit. A fixation solution consisting of 2.5 percent glutaraldehyde in 0.1 M PO_4 buffer then was perfused through the right cochlea. Typically, the left cochlea was not perfused except for immersion in fixative since the monauralization procedure resulted in virtually a complete destruction of the cochlea. After a variable length of fixation the right cochlea was postfixed in 1 percent osmium tetroxide in 0.1 M PO_4 buffer, washed, and dehydrated to 70 percent ETOH. The entire basilar membrane and stria vascularis were piecewise dissected free from their bony attachments and mounted in glycerin

on glass slides for a surface preparation, light microscopic analysis (Engstrom, et al., 1966).

Inner- and outer-hair cell populations were determined on a percentage basis as a function of distance along the cochlear duct. Baseline normal sensory cell populations were established at octave lengths along the cochlea using a large population (N=30) of normal chinchillas (Appendix D-5). Sensory cell counts which eventually yielded cochleograms were performed at a magnification of 500X using a Zeiss-Nomarski* light microscope. A cell was counted as missing when the cell body was not present. Alternatively, in animals that have survived more than 30 days after trauma, the location of missing cells usually is well marked by a characteristic phalangeal scar at the level of the reticular lamina. Cell counts were averaged over 0.24 mm lengths of the organ of Corti as measured along a reference line established by the junction of the inner and outer pillar cells at the highest level of the reticular lamina. A frequency-place map established by Eldredge et al., 1977 was used to superimpose frequency coordinates on the length coordinate of the cochleogram so that audiometric data could be directly related to the sensory cell populations along the length of the cochlea. All the light microscopic analyses and graphics were accomplished directly using an LSI 11/23 microcomputer system with the appropriate morphometric software developed in the histology laboratory. A complete presentation, by experimental group, of all individual cochleograms and superimposed PTS audiograms is presented in Appendix C. Octave band length, percent sensory cell losses, average percent losses across groups, and total sensory cell losses for individual animals are presented in Appendix D.

RESULTS

Preexposure Thresholds: A summary of all preexposure thresholds (dB SPL) for each animal in this study, as well as mean thresholds arranged by exposure groups (A through G) and mean thresholds for the entire group of 41 animals are listed in Appendix A. Figure 3 illustrates the tabulated thresholds taken from Appendix A. The upper curve represents the audiogram averaged across all 41 animals used in this study, while the lower sets of curves represent the average audiograms for each exposure group. The group average audiograms are presented in order to illustrate the relatively small amount of variability across the seven experimental groups, as well as the relatively close agreement with the normative data of Miller, 1970. Standard deviations for all the preexposure thresholds are presented in Appendix A.

Postexposure Threshold Shift: Figures 4 through 7 illustrate (for each exposure group) the group average maximum TTS (TTS max) measured, irrespective of when during the postexposure test period the maximum shift occurred. Each data point in these four figures was obtained as follows: The TTS max for a specific frequency was obtained for each individual animal in the exposure group and then these individual maximum threshold shifts were averaged, irrespective of when in time they occurred, to obtain the group average TTS max. These TTS max data are compared in each of Figures 4 through 7 with the respective TTS measured immediately after exposure (i.e., t=0). It is

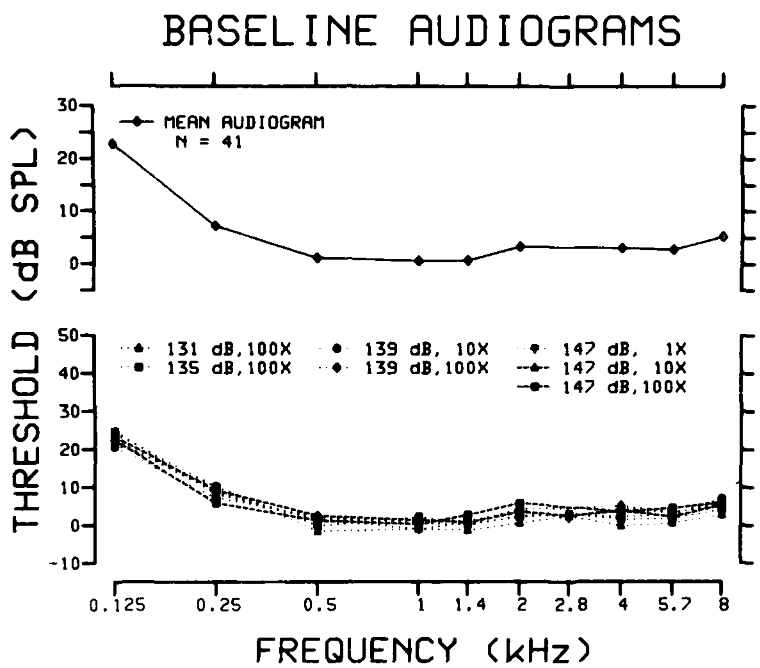

FIGURE 3. Mean preexposure audiograms for all 41 chinchillas (upper) and for the seven individual groups identified by exposure conditions (lower).

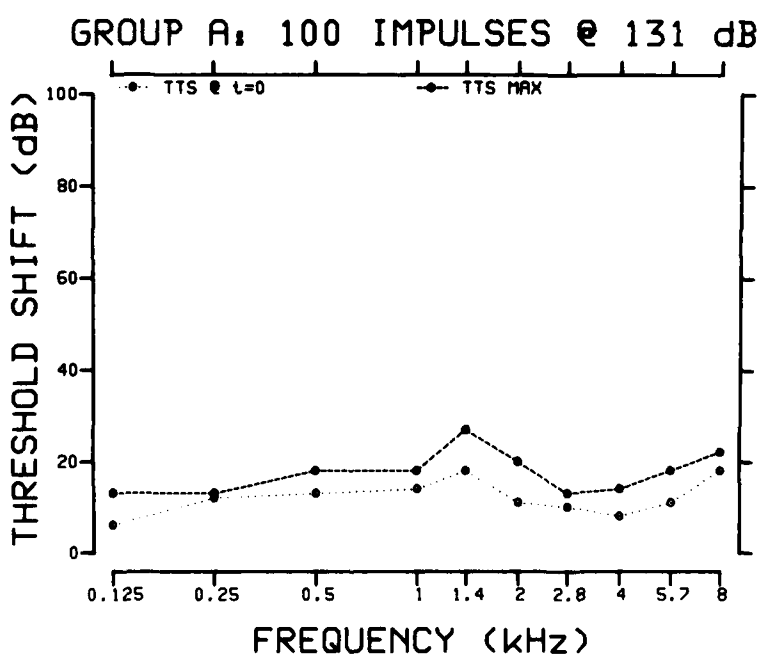

FIGURE 4. The postexposure mean group maximum TTS compared to the TTS measured immediately after exposure (TTS at t=0) for the animals exposed to 100 impulses at 131 dB.

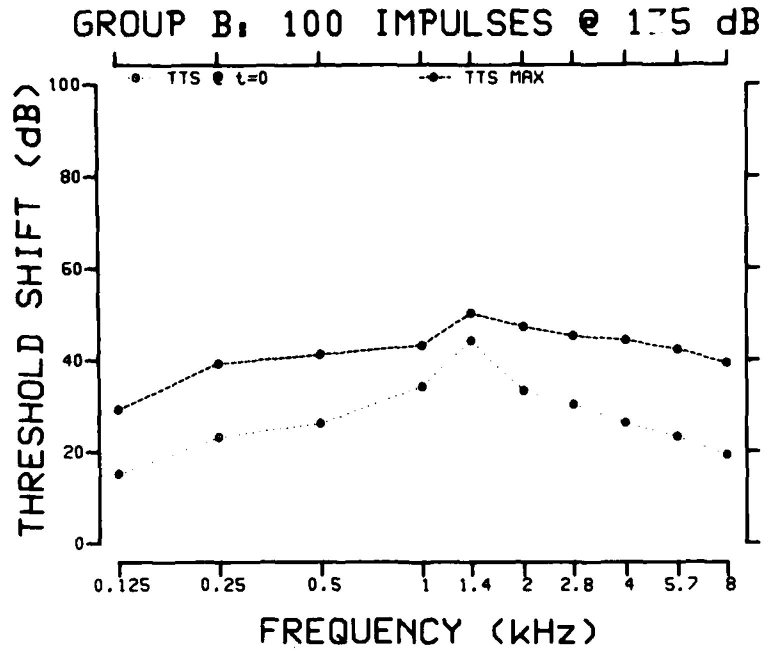

FIGURE 5. The postexposurє mean group maximum TTS compared to the TTS measured immediately after exposure (TTS at t=0) for the animals exposed to 100 impulses at 135 dB.

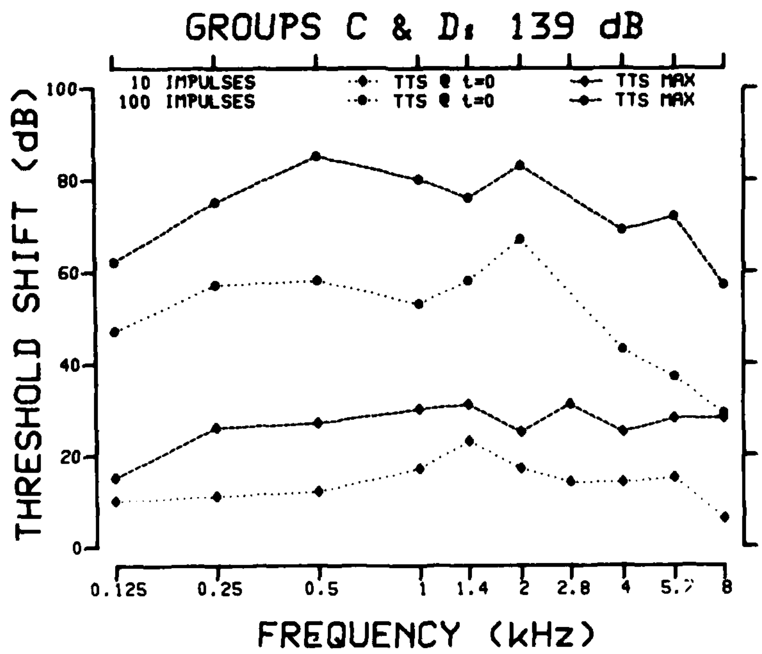

FIGURE 6. The postexposure mean group maximum TTS compared to the TTS measured immediately after exposure (TTS at t=0) for the animals exposed to either 10 or 100 impulses at 139 dB.

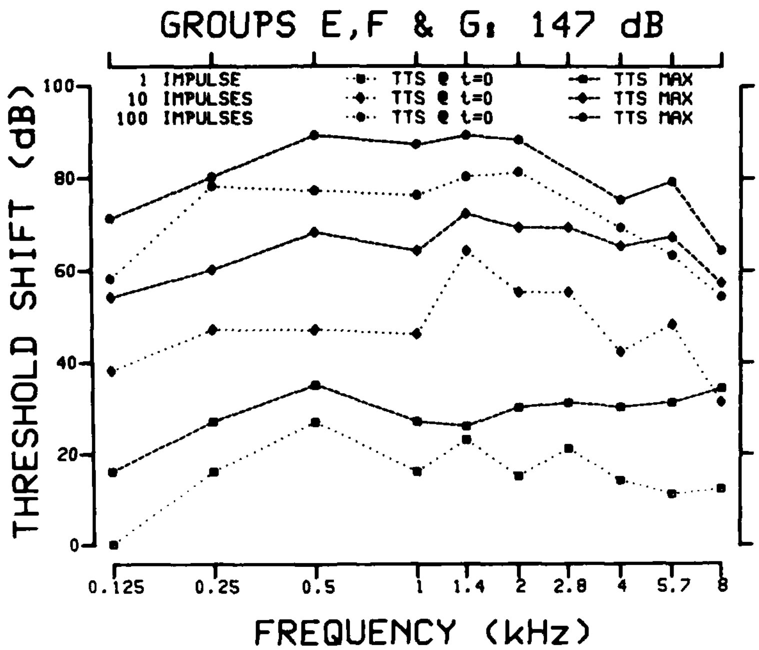

FIGURE 7. The postexposure mean group maximum TTS compared to the TTS measured immediately after exposure, (TTS at t=0) for the animals exposed to either 1, 10, or 100 impulses at 147 dB.

interesting to notice that in every exposure group, the maximum TTS does not occur at the first post-exposure test period (i.e, TTS max > TTS at t=0). This indicates that generally after these particular impulse noise exposures, thresholds continued to get worse for some time before a recovery process began.

Figure 8 illustrates the average TTS max for all seven groups of animals. The relative contributions of the intensity and number of impulses presented during exposure to the production of the TTS max can be estimated more readily from Figure 8. The TTS max for the animals receiving 100 impulses is well-ordered, with respect to intensity of exposure, i.e., the lowest level 131 dB produces the lowest TTS max which varies from approximately 10 dB through 20 dB across the range of test frequencies.

The series of four exposures at 100 impulses produced TTS max "audiograms" which were nearly all parallel to each other across frequencies. However, there is a significant nonlinearity, with respect to intensity, in the degree of TTS max. For a 4-dB intensity increase from 131 to 135 dB, the increase in TTS max averages around 30 dB while the 4-dB increase in intensity from 135 dB to 139 dB produces a considerably greater increase in TTS max (e.g., as much as 50 dB at .5 kHz).

Then for an 8 dB increase from 139 dB to 147 dB, a saturation effect appears to become operative and the increase in TTS max averages only around 10 dB. This saturation effect also can be seen in the three exposures done at

147 dB. As the number of impulses is increased from 1 to 10, the increase in TTS max is relatively large, averaging roughly 40-50 dB across the test frequencies, while a tenfold increase from 10 to 100 impulses produces only a 10-to-30 dB increase in TTS max.

The relative effect of increasing the number of impulses tenfold from 10 to 100 impulses also appears to be very intensity-dependent, probably because of the saturation effect. Notice the extreme differences in TTS max between the 10 and 100 impulse exposures at 139 dB compared to the comparable exposures at 147 dB.

Permanent threshold shifts across all test frequencies and for all experimental groups are illustrated in Figures 9 through 13. Figure 9 illustrates the effect of increasing the number of impulses as the intensity is kept fixed for the groups exposed to the 139 dB and 147 dB impulses. There was essentially no PTS for the 10 impulse exposures at 139 dB and the one impulse exposure at 147 dB. These two exposures have nearly the same energy. Similarly, the exposures of 100 impulses at 139 dB and 10 impulses at 147 dB have nearly the same energies, and their PTS audiograms are similar, generally overlapping at the higher frequencies (> 1 kHz) at a PTS of around 10 dB. While at the lower frequencies, the 139 dB exposure produced on the average approximately 10 dB more PTS than did the 147 dB exposure.

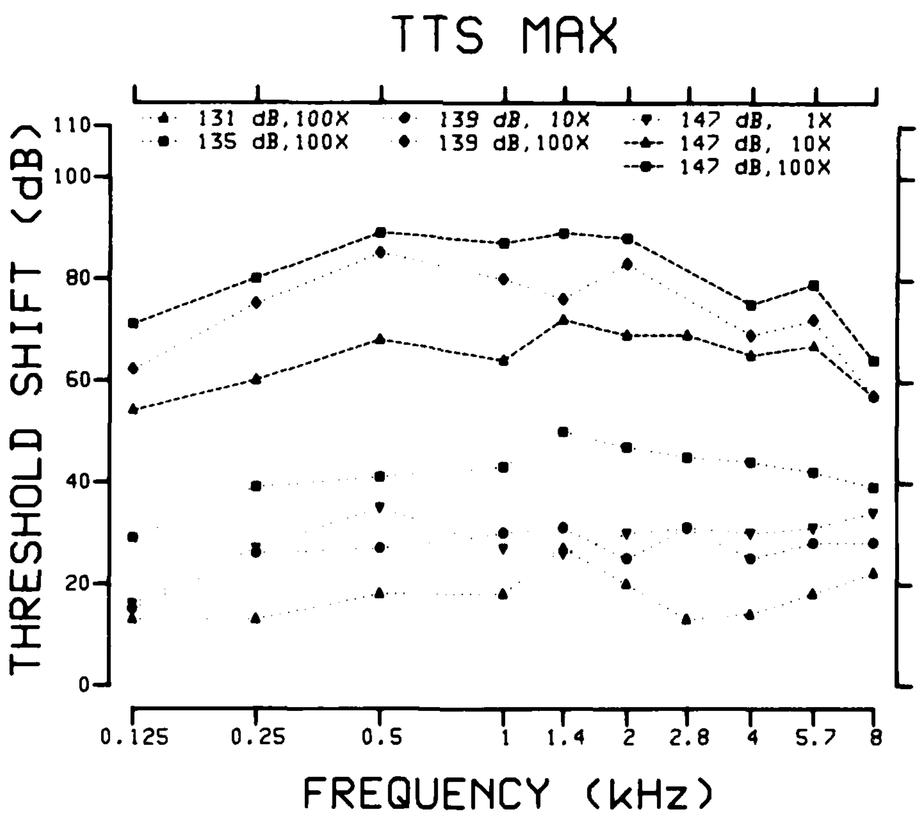

FIGURE 8. The postexposure mean group maximum TTS for all seven exposure groups.

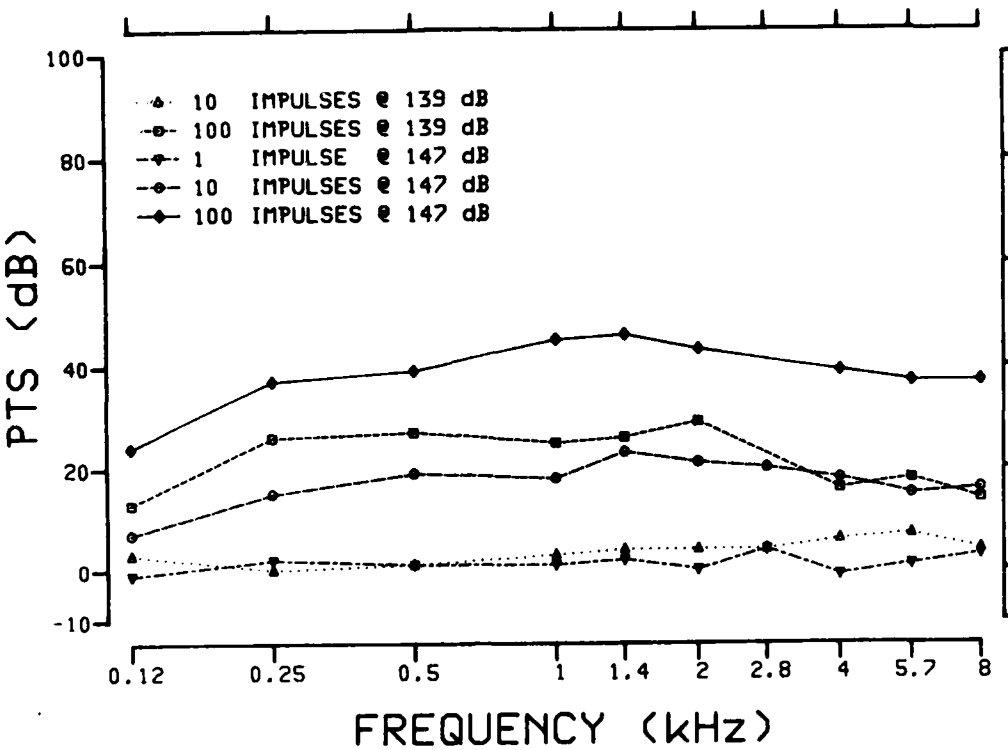

FIGURE 9. Group mean permanent threshold shift (PTS) audiograms for the 139 dB and 147 dB exposure conditions.

This tends to indicate that at least at some frequencies, the number of impulses may be more important than the intensity even though the exposures are equated for energy. The most severe exposure, i.e., 147 dB at 100 impulses produced a nearly flat loss of approximately 40 dB across all but the .125 kHz test frequency.

Summary (averaged) cochleogram data for the 139 dB and the 147 dB series of exposures are presented in Figures 10, 11 and 12. In Figures 10 and 11, each data point represents the average number (in percent) of hair cells lost in that particular experimental group (either inner or outer hair cells) within an octave band length of the cochlea centered at the frequency indicated (i.e., 0.125, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 kHz). The group average hair cell loss was computed by averaging the corresponding hair cell losses within the octave band lengths of the individual animals that constituted a particular exposure group.

The histological data presented in Figures 10 and 11 should be compared with the PTS data shown in Figure 9. For those exposures that produced no PTS, the sensory epithelia was normal as indicated by essentially no sensory cell losses in Figure 10 and 11. However, it is interesting to compare the audio-

gram and the sensory cell distribution for the 100 impulse 139 dB group. These animals sustained roughly a 20-25 dB PTS over most of the test frequency range, while their cochleas showed "on the average" very large (up to 80 percent) outer hair cell (OHC) losses which peaked at around 1kHz, while at and above the 8 kHz region of the cochlea and below the .25 kHz region, the sensory cell population is approximately normal.

In normal chinchillas the apical-most portion of the cochlea usually shows a scattered deficit of hair cells which rarely exceeds 15-20 percent. This is either an actual loss or a developmental anomaly. All the "average cochleograms" presented in this report can serve at best as only a relative index of sensory cell damage. With individual animal data, presented in Appendix D, the standard deviations for the sensory cell losses can be very high. This can be explained in two ways: (1) Some exposures appear to be near the threshold of a severe cochlear pathology and the animals tend to separate into two groups--those with comparatively smaller losses and those with extremely large losses; (2) the location of a lesion and the uniformity of the lesion with distance in the cochlea, even in similarly damaged animals, can vary appreciably. This can increase the variability in the octave band analysis of the sensory cell data. In addition to these two important points, the relatively small number

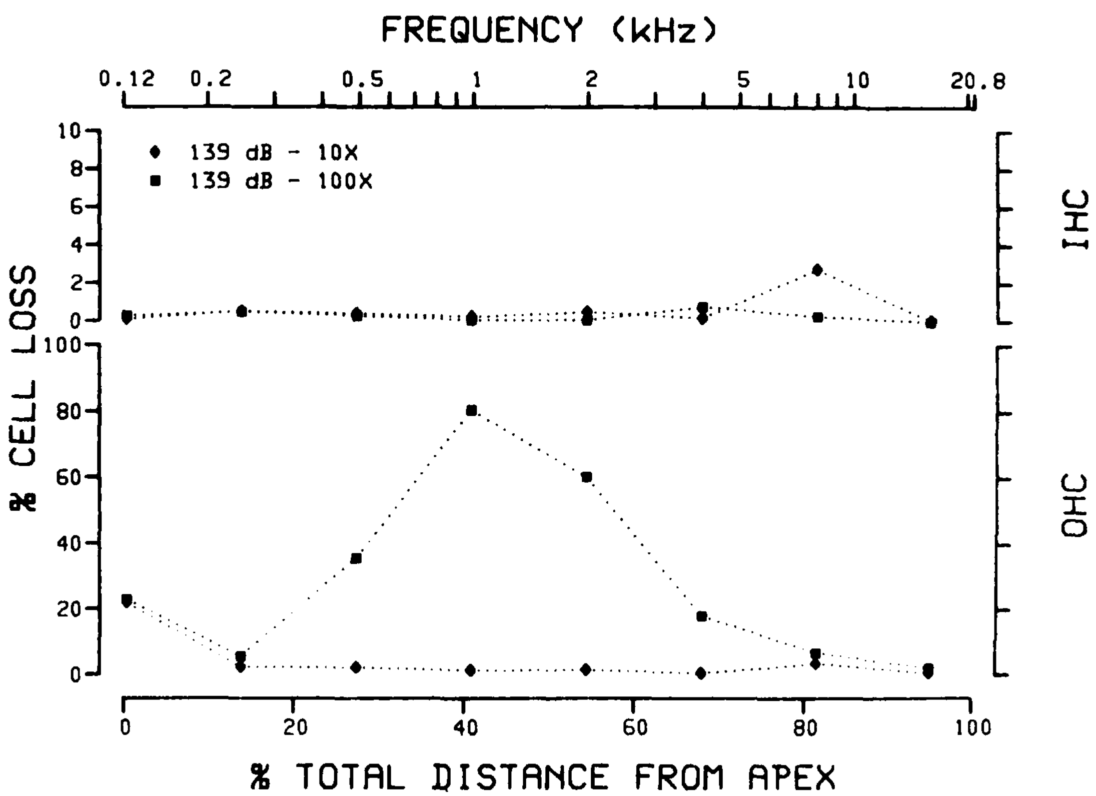

FIGURE 10. Group mean inner hair cell (IHC) losses and outer hair cell (OHC) losses computed over octave band length of the cochlea at the indicated frequencies for the 139 dB exposure conditions.

of animals in each group is yet another contributing factor. A precise distribution of sensory cell losses from a specific exposure condition only can be obtained from the individual animal data presented in Appendix C. In this appendix, the sensory cell data are presented with the PTS audiogram to allow for direct comparisons.

The sensory cell loss (both inner and outer hair cells) for the 147-dB exposure at 10 and 100 impulses had a different profile. The sensory cell loss at 10 impulses increased from the low frequencies, peaked at around 1 kHz with a 50 percent loss of OHCs and remained relatively flat (i.e., +/- 10 percent) up to 10 kHz. The inner hair cell (IHC) profile of loss was slightly more peaked and far less severe. A parallel loss was recorded at the 100-impulse exposure; however, the loss for OHCs amounted to nearly 100 percent throughout the region above 1 kHz. IHC losses showed a very similar profile and amounted to approximately 50 percent over the same region of the cochlea. Again, considering that the PTS for the 147 dB, 100-impulse exposure amounted

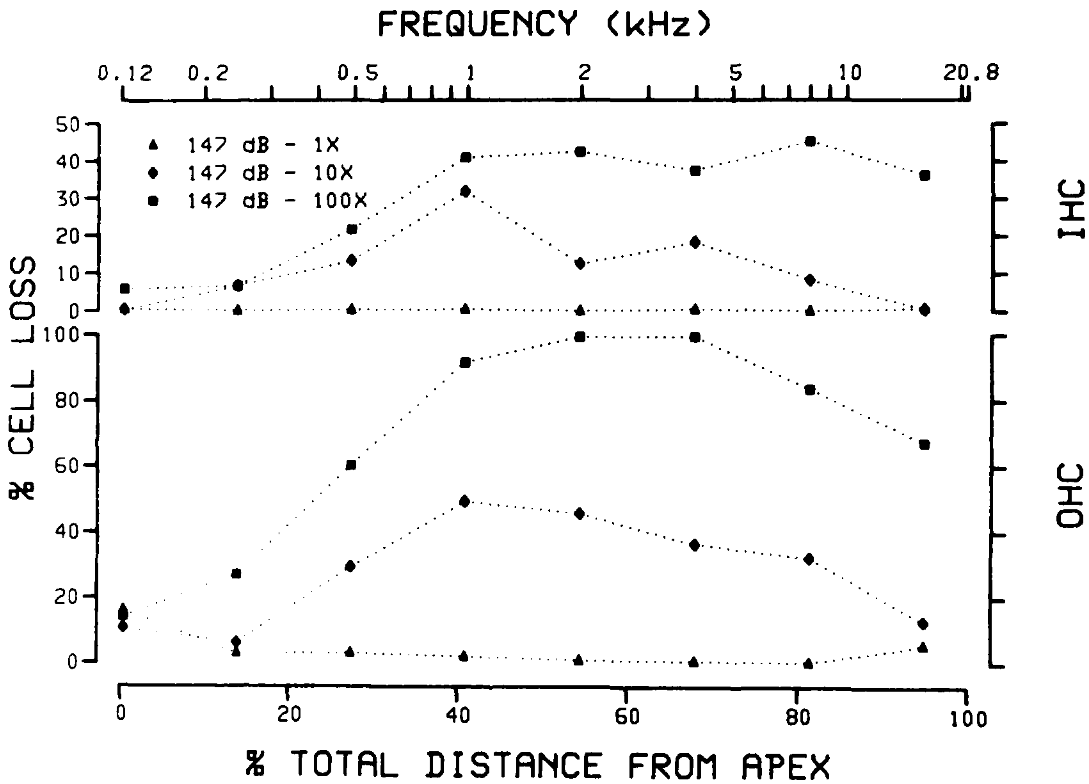

FIGURE 11. Group mean inner hair cell (IHC) losses and outer hair cell (OHC) losses computed over octave band lengths of the cochlea at the indicated freouencies for the 147 dB exposure conditions.

to a relatively flat 40 dB loss, it is surprising to have such severe sensory cell losses.

Figure 12 illustrates the total sensory cell losses averaged across each group in the series of exposures at 139 and 147 dB as a function of the number of presentations. Each data point in this figure was obtained by summing all the inner or outer hair cell losses throughout the cochlea for each animal in a specific group, and then averaging that total number across all the animals in that specific group.

Figure 12 indicates that at a given intensity, the sensory cell loss increases rather linearly with tenfold (logarithmic) increases in the number of impulses. The slope of the OHC loss, for example, is 2500 cells lost for each tenfold increase in number of impulses. This interpretation is at best tentative, and is subject to the earlier comments made concerning standard deviations in the histological data. The detailed data are presented in Appendix D. Taken together, Figures 9 through 12 allow comparisons to be made between the averaged sensory cell loss and averaged PTS over a range of parameters. In general, there is a congruence between the two groups of data.

A similarly obtained series of data are presented in Figures 13, 14, and 15. In this series of figures, the number of impulses presented to the animal is kept constant at 100 and the impulse level is varied from 131 through 147 dB.

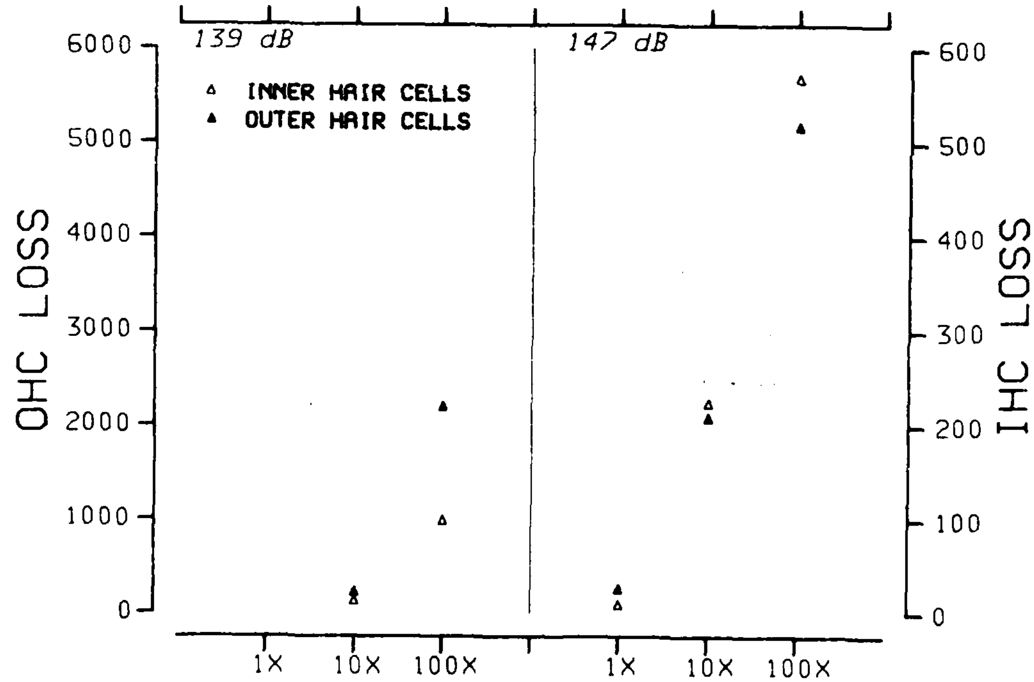

FIGURE 12. The group mean total number of inner (IHC) and outer (OHC) hair cells missing throughout the entire length of the cochlea as a function of number of impulses presented for the 139 dB and 147 dB intensities.

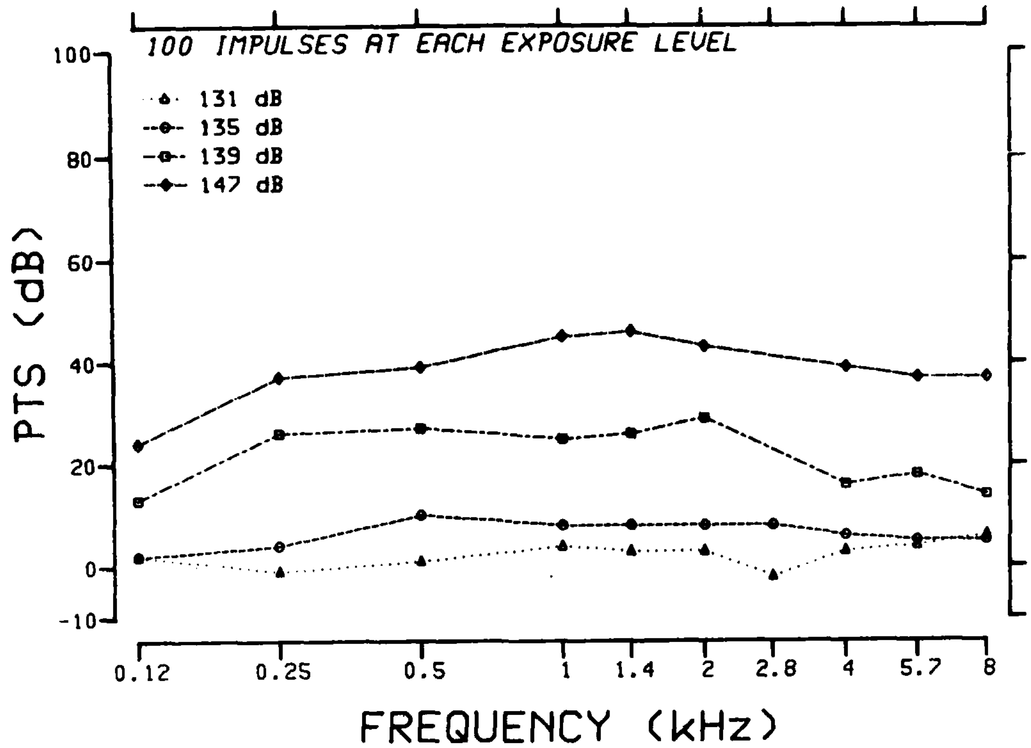

FIGURE 13. Group mean permanent threshold shift (PTS) audiograms for the groups exposed to 100 impulses at intensities of 131 dB, 135 dB, 139 dB, and 147 dB.

Once again, there is a relative rank ordering of both the histologica and audiometric data with respect to impulse level.

The PTS for the 100 impulse exposures vary from essentially no PTS at the 131 dB exposure to a flat 40 dB loss at the 147 dB exposure. The same kind of "nonlinearity" is evident in these PTS data as was discussed for the TTS max data in Figure 8, i.e., for a 4 dB level increase between the 131 and 135 dB exposures, the PTS for the 135 dB group shows only a marginal 5-10 dB increase over the 131 dB exposure, while the 4 dB increase from 135 dB to 139 dB exposure shows a generally broad 20 dB increase in PTS across the test frequency range. However, unlike the TTS max data the compressive effect between 139 dB and 147 dB exposures is not as pronounced, but nevertheless, the 40 dB PTS does appear to represent an upper bound to the PTS that could be obtained from these exposures.

The order of the PTS audiograms parallels the order of severity of sensory cell loss shown in Figure 14. Once again, the same qualifications concerning average sensory cell losses must be made as discussed for Figures 10, 11, and 12. Figure 14 is instructive in that it shows how, at the lower levels of exposure, the average sensory cell loss begins developing in a restricted area of the cochlea. The loss is initially localized around the 1 kHz area. (Note: The impulse spectrum shown in Figure 1 peaks near 1 kHz.) As intensity increases, the focus of the loss stays the same, but increases in its 1 kHz peak

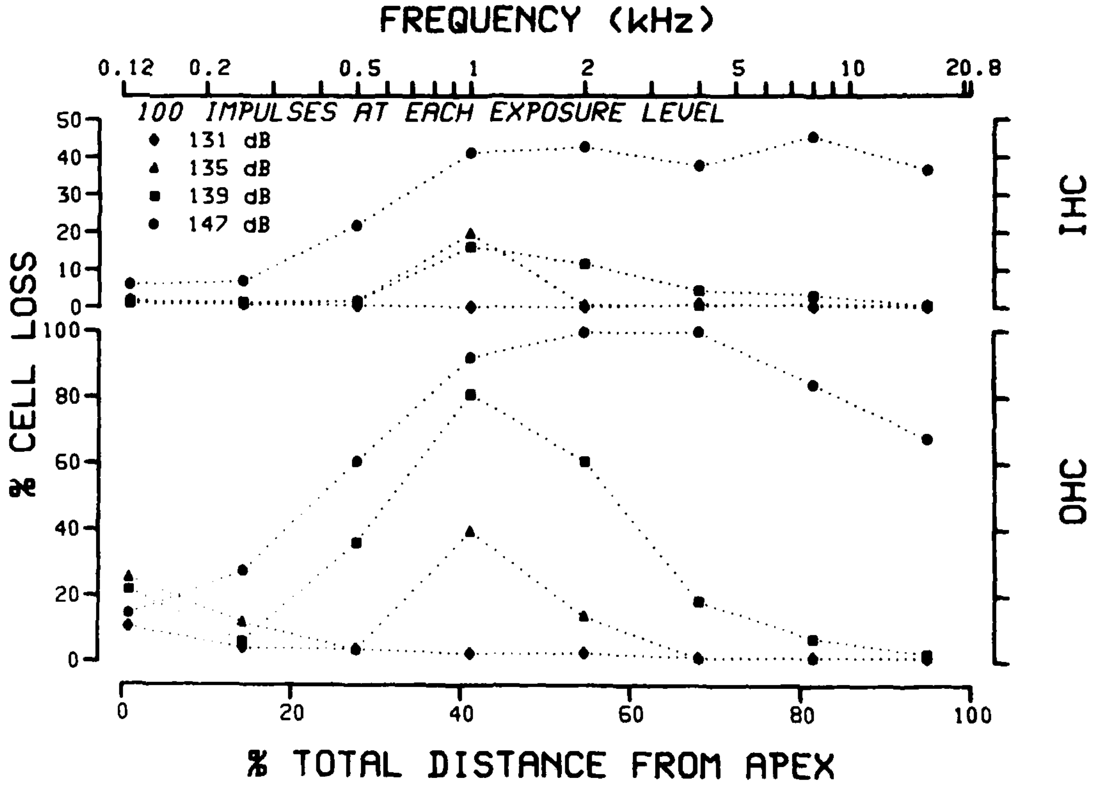

FIGURE 14. Group mean inner hair cell (IHC) losses and outer hair cell (OHC) losses computed over octave band lengths of the cochlea at the indicated frequencies for the groups exposed to 100 impulses at intensities of 131 dB, 135 dB, 139 dB, and 147 dB.

and begins to broaden noticeably. Finally, at the highest level, the OHC losses peak out at 100 percent and the broadening effect severely increases into the higher frequency regions of the cochlea, and much less so toward the lower frequencies. The effects on the IHC population are similar except that the average loss peaks at 50 percent for the 147 dB exposure.

Figure 15 illustrates the average total IHC and OHC loss for the 131 to 147 dB intensity series at 100 impulses. While there is an orderly relation with respect to intensity in the average data, there does appear to be a rapidly accelerating sensory cell loss as the impulse level is increased.

Figures 16 through 19 illustrate surface preparation micrographs that are representative of the kinds of impulse noise-induced pathologies that were seen in the various exposure groups. Figure 16A shows the typical appearance of the sensory cells from the groups that showed little or no PTS; the sensory cell population is essentially normal. As the level of the impulse or the number of impulses was increased, the sensory cell damage rapidly increased. Figure 16B (insert) illustrates a one-half turn of a cochlea with a severe IHC and OHC loss (dashed line). Figure 16B is an enlargement of the basal edge of the lesion seen in the insert. At the

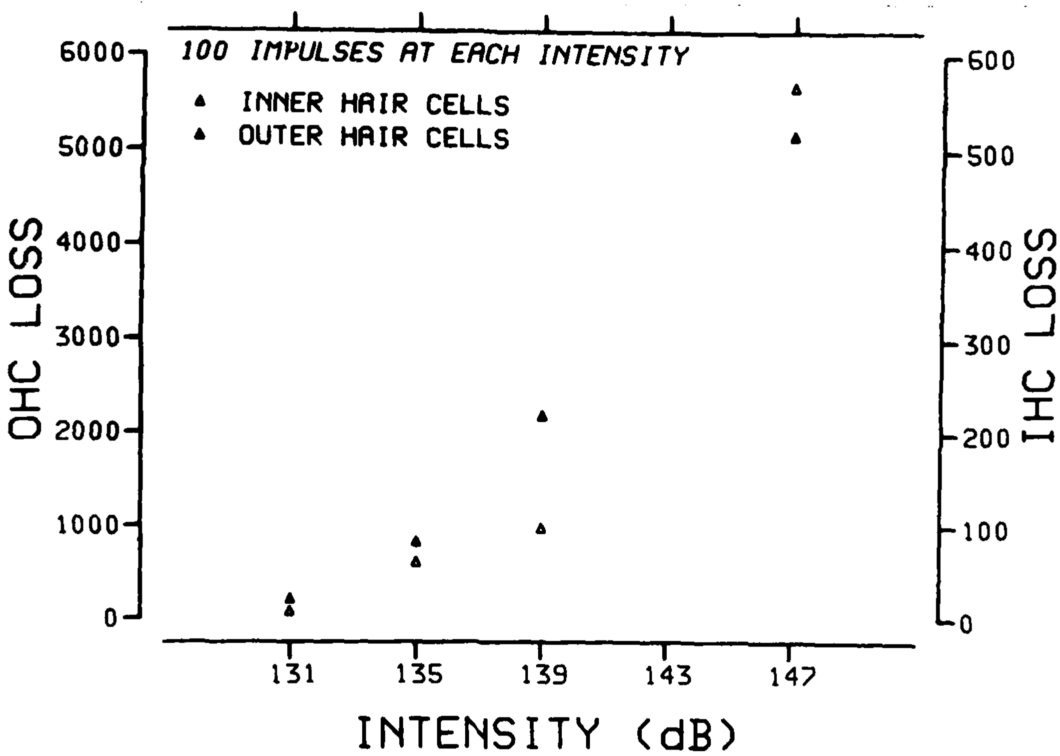

FIGURE 15. The group mean total number of inner (IHC) and outer (OHC) hair cells missing throughout the entire length of the cochlea for the groups exposed to 100 impulses as a function of impulse intensity.

margin of the lesion, the IHC population is normal and pillar cells are normal, but many outer hair cells (arrow head) still are missing. The edge of the lesion is very abrupt. The sequence of plates in Figures 17A-C illustrates the variable appearance of the lesion in different locations in the same animal. In plate A, most of the OHCs are missing; pillar cells are damaged, but IHCs generally are present. In some animals (e.g., J8R, Figure 18A), very punctate lesions were found which resulted in losses of IHCs, OHCs, pillar cells, and myelinated nerve fibers. (Note the lighter appearance of the micrograph in the myelinated nerve fiber area of Figure 18A.)

The most severe lesions were typically the 147 dB exposures illustrated in Figures 18B-D and Figure 19. These lesions frequently consisted of large areas of the basilar membrane without any sensory or neural elements being present (Figures 19C-D), and with only epithelial scar tissue covering the basilar membrane. In general, the detailed pattern of the epithelial cell damage on the basilar membrane was very variable and simple cochleograms did not always convey an accurate picture of the specific nature of the pathology.

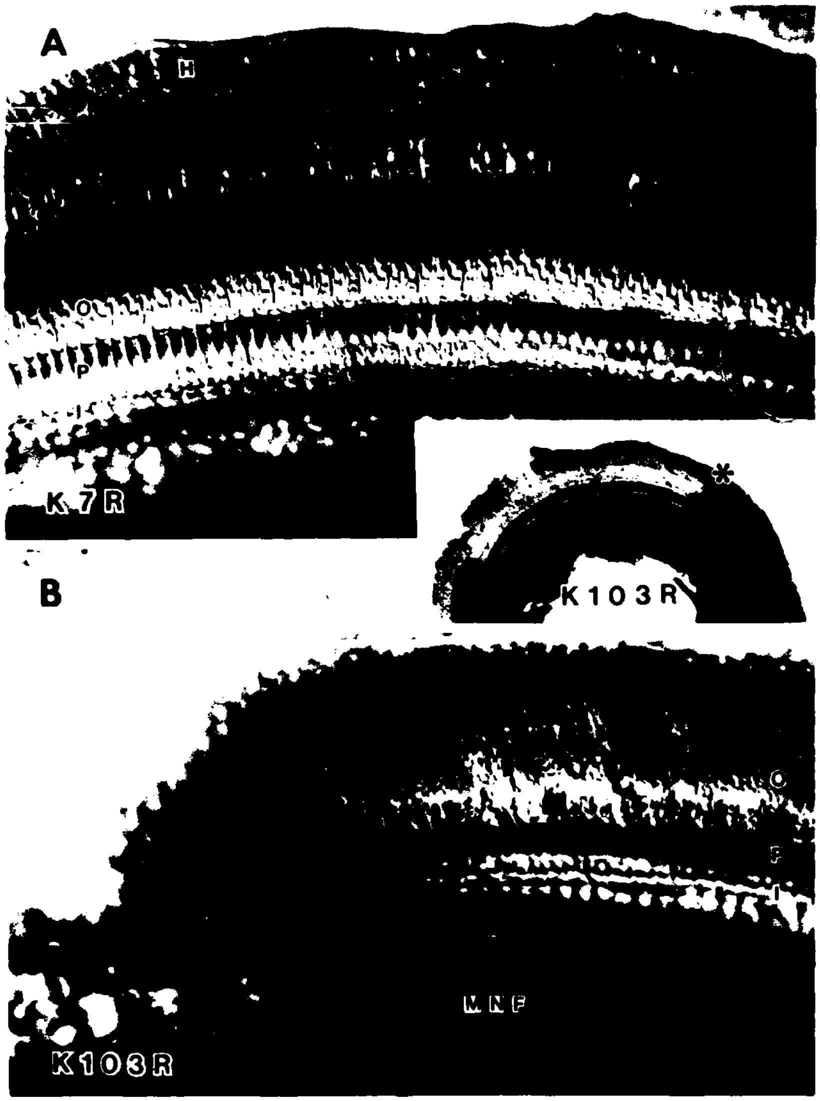

FIGURE 16. A). Surface preparation of an impulse noise exposed animal (K7R) typical of those that did not sustain a sensory cell pathology (exposure: 131 dB; 100X). H - Hensen cells; O - outer hair cells; P - pillar cells; I - inner hair cells.
Insert: Example of a severe lesion (dotted line) extending throughout approximately 1/3 of a cochlear turn from animal K103R (exposure: 135 db; 100X). * - indicates area of enlargement in plate B.
B) Enlargement of the basal edge of the lesion seen in the insert. ▶- indicates scars at the level of the reticular lamina where outer hair cells are missing. (Note the complete loss of sensory epithelia on the left side of this plate.) O - outer hair cells; P - pillar cells; I - inner hair cells; MNF - myelinated nerve fibers.

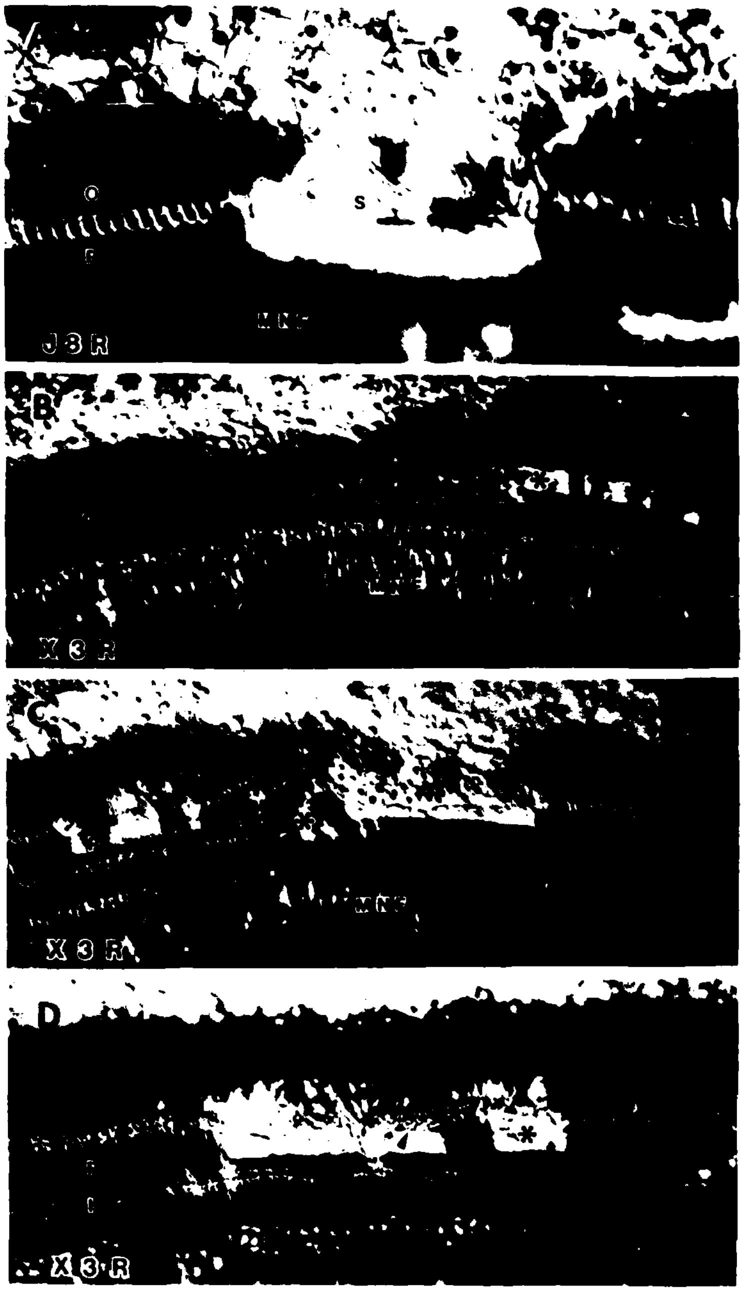

FIGURE 17 Three examples of the damaged organ of Corti taken from different areas of the cochlea in animal H16R (exposure: 139 dB; 100X). Note the general absence of outer hair cells in all three plates; H - Hensen cells; P - pillar cells; I - inner hair cells; MNF - myelinated nerve fibers; * - indicates pillar cell lesions; ▶ - indicates scar tissue that has replaced damaged outer hair cells.

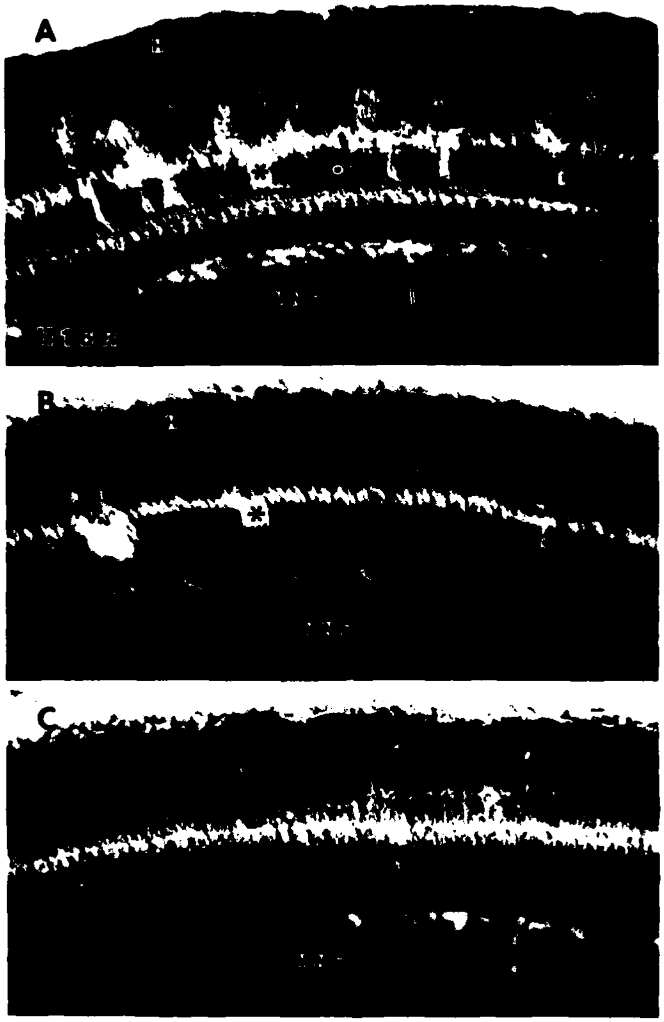

FIGURE 18. A) Example of a very punctate kind of lesion where all the sensory and supporting structures have been replaced by scar tissue (S). (Note the light area where there is a deficit of myelinated nerve fibers - MNF). This surface preparation speciman was taken from animal J8R (exposure: 139-dB; 10X).

B-D) Surface preparation micrographs taken from animal X3R (exposure: 147-dB; 10X) showing the changing appearance of the lesion in a given animal. In plate B, virtually all the sensory cells and many of the supporting cells are missing. The myelinated nerve fiber (MNF) density is particularly low. In plates C-D, outer hair cells and pillar cells are missing; however, some inner hair cells are present. P - pillar cells; O - outer hair cells are present; I - inner hair cells; MNF - myelinated nerve fibers; * - indicates pillar cell loss; ▶ - indicates scar formation at the level of the reticular lamina.

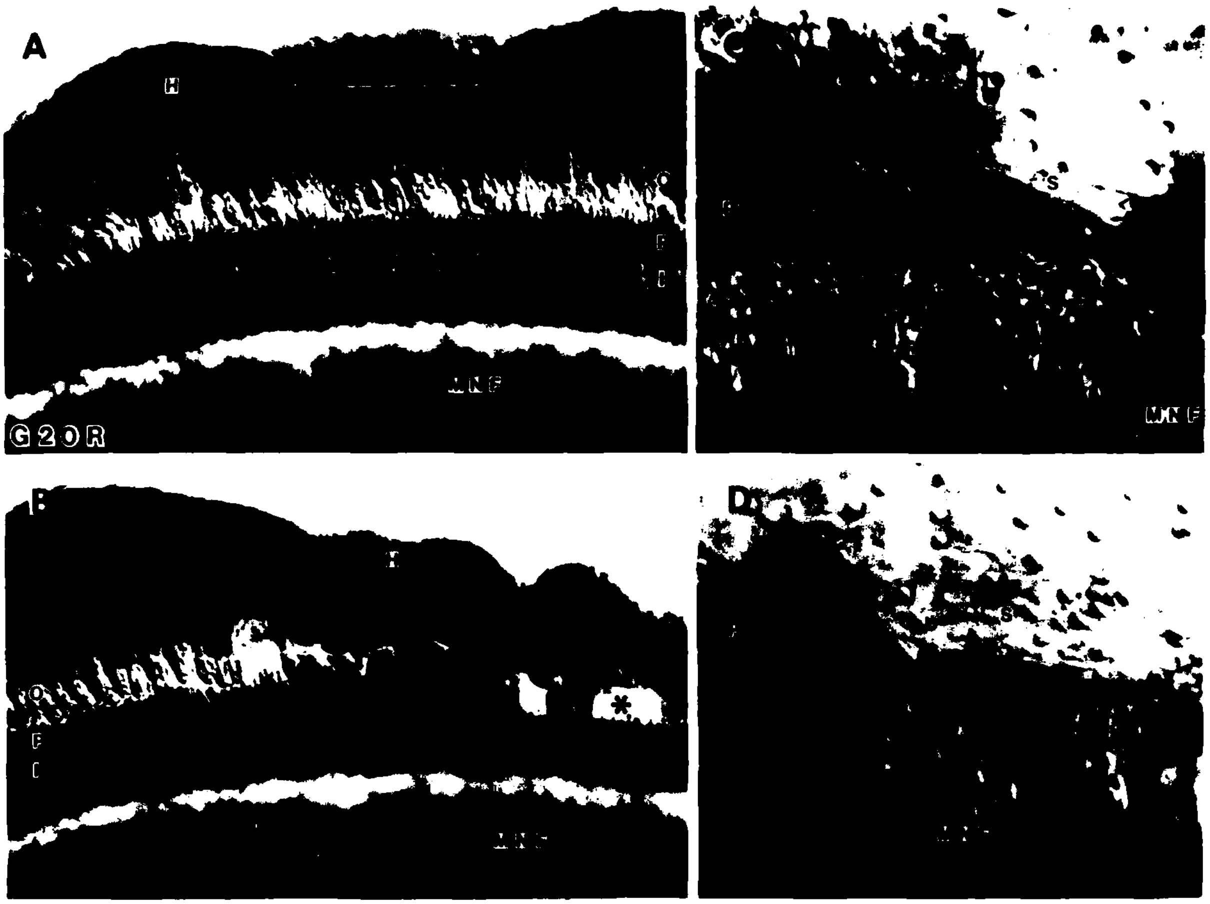

FIGURE 19. Surface preparation micrographs taken from animal G20R (exposure: 147-dB; 100X).

A) Illustrates a focal lesion in the area of the Hensen cells (arrow), inner hair cells (I) are generally present, and many of the outer hair cells (O) are also present.

B) The apical edge of a more severe region of the lesion involving a complete loss of outer hair cells, Hensen cells, pillar cells and some inner hair cells.

C-D) Examples of the most severe type of damage where all the sensory and supporting elements on the basilar membrane are replaced by a simple epithelial layer (S). (Note the reduction in myelinated nerve fibers.) P- pillar cells; O - outer hair cells; I - inner hair cells; H - Hensen cells; S - scar tissue; ▶ - indicates missing outer hair cells; * - indicates missing pillar cells; MNF - myelinated nerve fibers.

DISCUSSION

Most of the significant observations that were derived from these experiments already have been discussed in the results section. However, a few of the more salient points will be addressed.

The spectrum of the impulse used contains very little energy below 0.5 kHz and above 4 kHz, but the patterns of TTS, TTS max, and PTS across the 0.125-to-8-kHz test frequency range were relatively flat. Considering the impulse spectrum, it was surprising that there was a large, as well as an orderly shift at 0.125 kHz and 8 kHz. The impulse spectrum peaked in the 1-1.5-kHz region, and in much of the TTS data at t=0, there tends to be a slight peak in the 1-to-2-kHz region. Even in the PTS data of Figures 9 and 13, there is a slight tendency for the curves to peak in the 1-to-2-kHz region. However, the strongest relation is between the impulse spectrum and the appearance of the lesion on the organ of Corti. In Figures 10 and 14, it is very clear that on the average the lesion begins very distinctly at the 1-kHz region of the cochlea and increases in severity as the severity of the exposure increases. Furthermore, a review of the histological data presented in Figure 14 confirms one's intuitive feelings for how the lesion should grow with intensity, i.e., the strong high-frequency spread of the lesion and the more restricted low-frequency spread would tend to agree with the current concepts of the traveling wave on the basilar membrane.

Figures 4 and 7 confirm a phenomenon that frequently is observed following impulse noise exposure (Henderson and Hamernik, 1982; Luz and Hodge, 1971), i.e., that the maximum TTS does not always occur immediately following the termination of an exposure. These figures indicate that hearing continues to get worse after exposure, for a period which may be as long as 10 hours post-exposure, before recovery actually begins. This phenomenon was observed in all the exposures documented in this report. The reasons for this are obscure. Regardless of why TTS grows following exposure, the important point is that using the traditional measure of TTS at t=0 to judge the hazard potentials of an impulse noise exposure is not entirely justifiable. Such a nonlinear TTS recovery function following impulse noise exposure differs from that following exposure to a continuous noise where TTS begins to immediately recover in an approximately linear-in-log-time manner. Our TTS results would question the value of using TTS as a measure of the potential trauma associated with impulse noise exposure. The TTS issue is still a viable one since current DRC/s for exposure to impulse noise are based upon TTS measures.

The seven exposure conditions chosen for the experiments reported here further indicate that a trauma to the cochlea could be produced by a relatively small change in the parameters of an exposure, e.g., a 4-dB increase in impulse level produces a disproportionate increase in cochlear damage and PTS (Figures 13 and 14). Observations such as these would indicate that a critical combination of variables exists, such that exposures to combinations of variables below the critical combination would be relatively safe while above this critical point, damage to the cochlea would accumulate very rapidly. The idea of a critical level has been debated a number of times. There is increasing data to indicate that there is in fact a critical level of impulse

noise for injury. However, impulse level is only one variable out of a multitude that must be known to accurately specify an impulse noise exposure. Conceivably, each of the variables can interact to produce sets of critical conditions.

The limited range of exposure parameters in this study is insufficient to shed much light on such concepts as the equal energy hypothesis; however, the two pairs of exposures, (10 impulses at 139 dB and 1 impulse at 147 dB; 100 impulses at 139 and 10 impulses at 147 dB) have roughly the same energy and they did produce similar amounts of TTS and PTS. However, this limited agreement with the EEH is extremely tenuous for at least two reasons: (1) the less severe of the exposure pair produced no PTS or sensory cell loss, thus both exposures were below the threshold for trauma; and (2) the nonlinear growth of various measures of trauma with the impulse parameters used in this study weakens the arguments in favor of the EEH.

After the data had been acquired and analyzed from Groups C through G, the predictive scheme shown in Figure 20 was developed. This figure relates the permanent threshold shift averaged at 1, 2, and 4 kHz ($\overline{PTS}_{124}$) to the

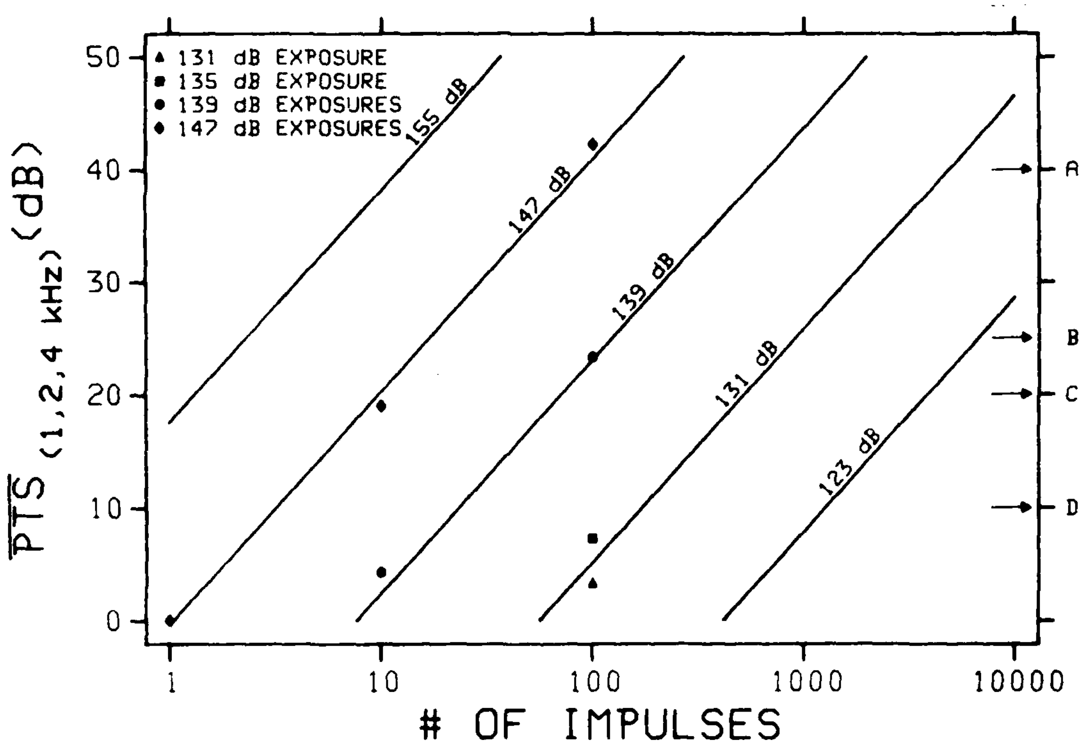

FIGURE 20. The mean PTS computed at 1, 2, and 4 kHz as a function of the number of impulse presentations with intensity as a parameter. Symbols indicate experimental data points; solid lines indicate the predicted variation of the intensity parameter; letters A through D indicate levels of $\overline{PTS}_{124}$ that produce specific degrees of histological damage.

number of impulses with impulse intensity as a parameter. The slope of the lines was chosen to fit the data for the 147 dB exposures. The spacing between lines is based on an equal energy trading of 10 dB intensity for a tenfold change in number of impulses. The relative linearity of the 147 dB and 139 dB data led to the additional exposures at 131 dB and 135 dB. While the 131 dB data are approximately where Figure 20 would predict, the 135 dB data are lower than predicted.

This figure, however, does illustrate some interesting points: (1) Based on these limited data, this figure would predict a trading relation between impulse, intensity, and number of impulses of 10 dB per tenfold change in impulse number for equal hazard where equal hazard is defined as equal $\overline{PTS}_{124}$. The CHABA predictions indicate a 5 dB trading relation per tenfold change; (2) The letters A through D on Figure 20 are meant to illustrate that levels of $\overline{PTS}_{124}$ can be useful in rating histological damage. For example, an exposure that produces $\overline{PTS}_{124}$ = 10 dB is generally considered to be safe with only very small amounts of lost sensory cells (point D); for a $\overline{PTS}_{124}$ = 20 dB, approximately 50% of the exposed animals will have very severe sensory cell losses (point C); for a $\overline{PTS}_{124}$ = 25 dB, 100 percent of the animals can be expected to have severe sensory cell lesions (point B); and finally, when $\overline{PTS}_{124}$ = 40 dB, there are very few sensory cells left in the cochlea.

In order to clarify the implications of our results for the equal energy hypothesis, the data are replotted in Figure 21 to show $\overline{PTS}_{124}$ as a function of

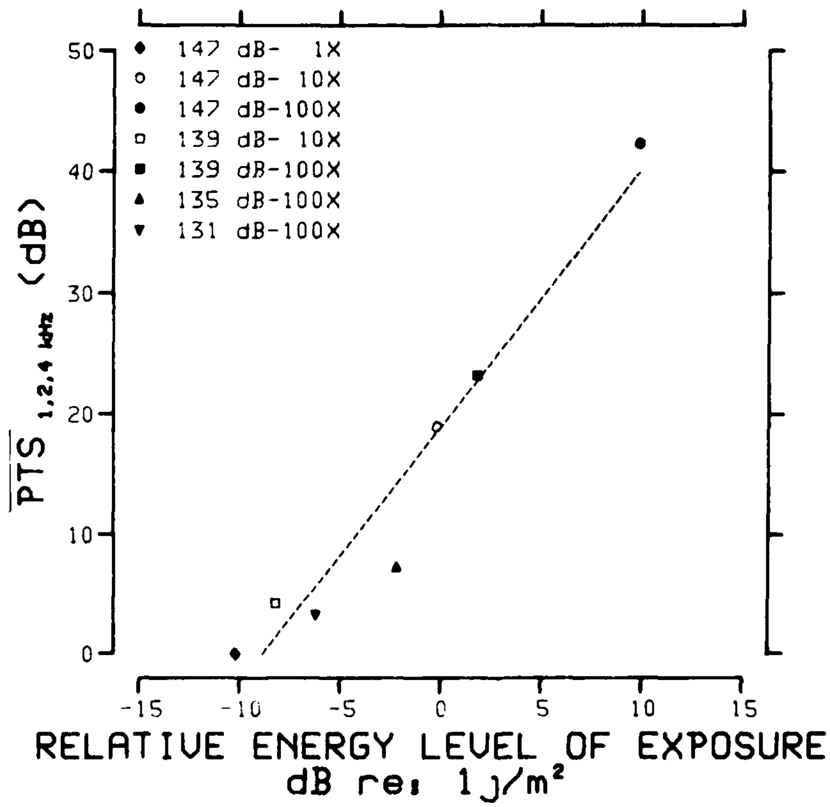

FIGURE 21. The mean PTS computed at 1, 2, and 4 kHz as a function of the total exposure energy.

exposure energy (see Appendix E.) It is clear that the 147 dB and 139 dB are well fitted by a line with 20 dB $\overline{PTS}_{124}$ per 10 dB of energy. This is consistent with an equal energy concept to predict both the threshold of injury and extent of injury as measured by $\overline{PTS}_{124}$. The lower level exposures depart from this pattern, suggesting that for some critical combination of intensity and level the relationship between $\overline{PTS}_{124}$ and energy changes. Particularly the 135 dB exposure produced less PTS than would be expected from energy considerations.

Figure 22 shows the mean outer hair cell loss as a function of exposure energy level. The average numbers of missing sensory cells were converted to dB levels by referencing the OHC loss to 100 cells and the IHC loss to 10 cells. The assumption implicit in the choice of reference numbers is that sensory cell losses of this magnitude are comparatively normal if the loss is scattered uniformly throughout the cochlea, or that if the loss is confined to a very narrow region of the cochlea the loss would be difficult to identify by our available testing procedures. In this latter case the cochlea could

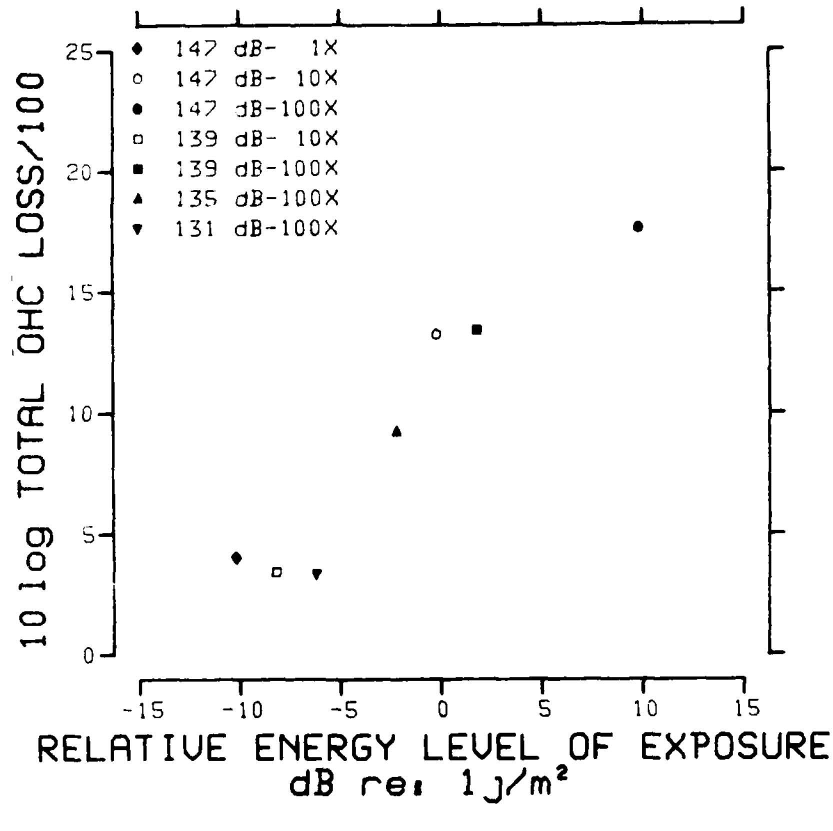

FIGURE 22. Total group mean outer hair cell loss as a function of total exposure energy.

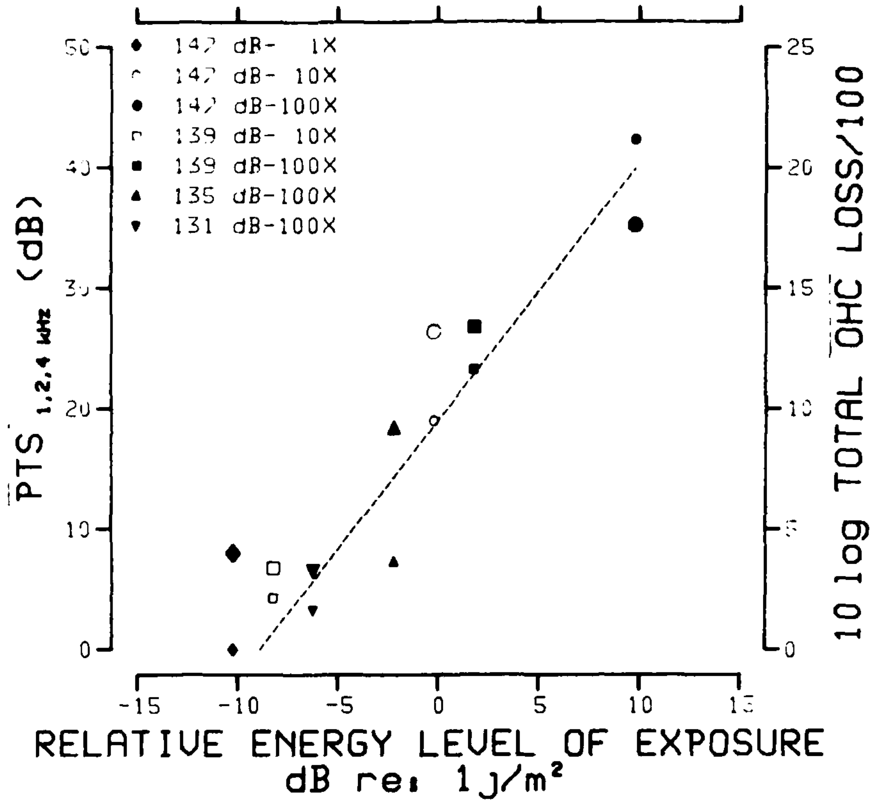

FIGURE 23. Mean PTS at 1, 2, and 4 kHz (small symbols) and total group mean outer hair cell loss (large symbols) as a function of total exposure energy.

not be considered normal. In Figure 22 there is a general agreement between the extent of sensory cell loss and the energy level of the exposure. In order to more clearly demonstrate the correspondence between the average PTS and the mean outer hair cell loss, the data of Figures 21 and 22 have been combined into Figure 23. Even though no two exposures contained the same energy, the fact that over a range of intensities and for the number of impulses used, both the average PTS and the mean outer hair cell loss show an orderly relation to energy level is supportive of an EEH. A similar conclusion can be drawn from an analysis of the mean inner hair cell loss shown in Figure 24 as a function of the energy level of the exposure. These results are particularly interesting since the inner hair cells account for something on the order of 95% of the afferent nerve fibers leaving the cochlea (Spoendlin 1969, 1972). The preceding discussion should further be tempered by noting that the use of PTS_{124} as an audiometric index of trauma is completely arbitrary. For the exposures used in the set of experiments

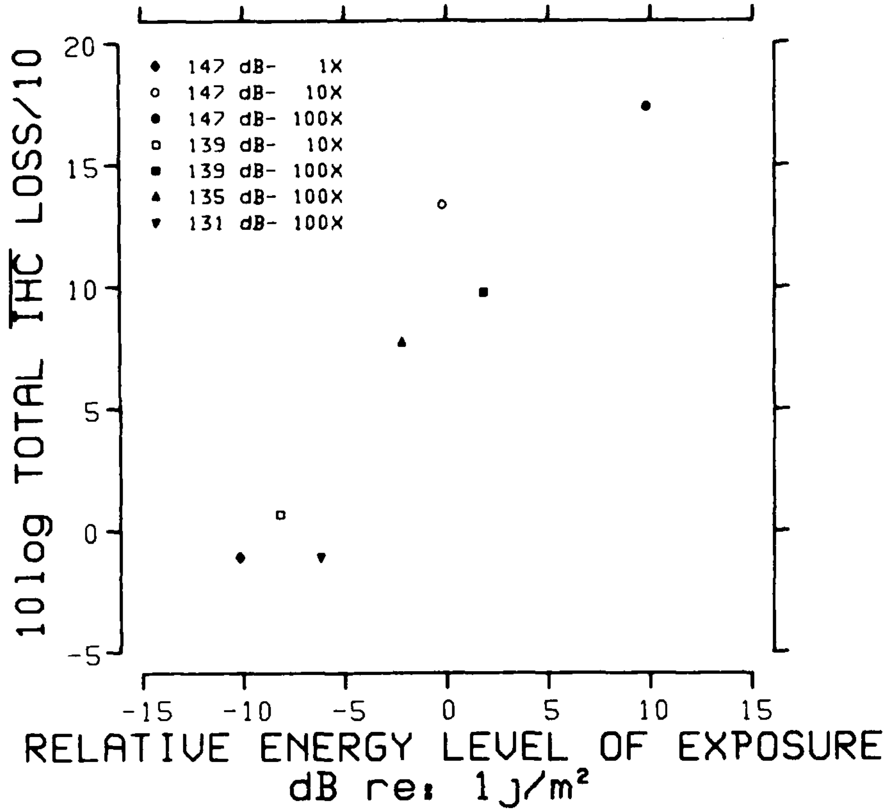

FIGURE 24. Total group mean inner hair cell loss as a function of total exposure energy.

reported here, PTS was relatively flat across the range of audiometric frequencies tested. However, for a set of exposure conditions which produce an irregular PTS profile (e.g., the classic 4 kHz notch), the orderly relation between trauma ($\overline{PTS}_{124}$), sensory cell loss and energy of the exposure may prove to be only fortuitous. Clearly, more exposure conditions are necessary before the approach used in Figures 20 through 24 and the conclusions drawn from these figures can be better justified.

In spite of the above reservations, the results reported here indicate that for some range of exposure conditions the conventional rule of a 5 dB change in intensity for a tenfold change in the number of impulses is not an accurate reflection of the hazard to hearing posed by impulse noise exposures. The generality of the present finding, i.e., a 10 dB intensity change for a tenfold change in the number of impulses, will have to be determined by more extensive parametric studies covering a wider range of impulse parameters. Pending the outcome of future studies, the current 5 dB trading rule should be used with caution.

CONCLUSIONS

For the impulses used in this study there is a range of intensities which is bounded on the high side by the intensity which just produces injury (PTS or outer hair cell loss) with single impulse exposures and bounded the low side by a critical intensity below which the injury potential drops precipitously with reduction of impulse intensity. This region is only about 10-15 dB wide for the exposure conditions of this experiment. Within this region the threshold of injury is a constant total energy (i.e., 10 dB change of intensity implies a tenfold change in number of impulses for threshold injury.) Over this range of intensities the extent of injury as measured by PTS grows at 20 dB per dB of energy. At impulse intensities below this range there is evidence that the threshold of injury is an increasing function of total energy. There is not sufficient data in this experiment to determine this function or its extent. There is, also, insufficient data to determine the functional relationship of total energy to extent of injury.

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APPENDIXES

APPENDIX A

Preexposure baseline audiograms for each animal used in this study: The individual animals are arranged by exposure groups*.

Two types of summary audiograms are presented:

(a) Mean baseline audiograms for the entire exposure group; and
(b) A single mean baseline audiogram for all the animals (N=41) used in this study (page A9).

The standard deviation (SD) for each mean measure is presented.

*The exposure groups are identified as follows:

Group A - 100 impulses @ 131 dB

Group B - 100 impulses @ 135 dB

Group C - 10 impulses @ 139 dB

Group D - 100 impulses @ 139 dB

Group E - 1 impulse @ 147 dB

Group F - 10 impulses at 147 dB

Group G - 100 impulses @ 147 dB

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (A) 100 Impulses at 131 dB:

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
J34	X	22	12	-3	-2	-4	2	0	1	0	5
	SD	4.1	5.6	4.6	3.0	3.2	4.1	6.4	6.1	4.1	3.0
J35	X	19	9	4	-1	1	5	7	4	-1	4
	SD	3.2	3.2	3.2	8.4	3.2	4.5	3.2	3.2	6.3	3.2
K5	X	23	11	0	3	-1	3	5	2	1	2
	SD	1.8	3.9	1.8	3.8	3.9	5.8	3.4	1.8	1.8	1.8
K7	X	20	8	-7	-8	-8	-10	-4	-5	0	-1
	SD	4.4	3.3	7.8	5.5	4.8	3.0	6.4	7.8	7.3	3.0
K105	X	23	11	-2	3	5	3	4	0	3	4
	SD	4.4	4.1	4.8	9.1	8.1	8.3	5.0	4.8	7.7	2.3
	GM*	21.4	10.2	-1.6	-1.0	-1.4	0.6	2.4	-0.2	0.6	2.8
	SD	1.8	1.6	4.0	4.5	4.9	6.0	4.4	2.8	1.5	2.4

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (B) 100 Impulses at 135 dB:

Animal #		Test Frequency (kHz) .125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
G21	X	26	9	4	1	1	3	3	-2	-1	8
	SD	5.0	3.0	4.4	2.3	3.3	6.4	8.2	5.9	3.3	2.3
K68	X	24	12	3	2	2	2	3	5	4	9
	SD	2.9	4.1	2.2	4.7	3.6	3.6	3.6	2.2	2.2	7.5
K103	X	32	8	-5	2	-4	-2	2	-1	4	3
	SD	1.4	5.5	6.0	2.7	5.4	5.2	7.6	4.2	6.1	7.2
K108	X	24	12	-5	-2	2	4	4	3	0	1
	SD	5.0	3.0	3.3	5.9	3.4	3.8	3.8	3.8	4.7	4.7
K116	X	20	10	5	4	0	2	6	1	2	1
	SD	3.2	4.5	3.2	3.2	4.5	3.2	3.2	4.5	3.2	3.2
H184	X	18	10	-3	6	0	4	2	3	2	3
	SD	3.0	3.0	2.7	3.6	2.7	4.3	3.2	3.6	4.3	3.6
	GM*	24.0	10.2	-0.2	2.2	0.2	2.2	3.0	1.5	1.8	4.2
	SD	4.9	1.6	4.7	2.7	2.2	2.2	1.8	2.7	2.0	3.5

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (C) 10 Impulses at 139 dB:

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
J10	X	20	7	3	-1	-2	4	2	1	5	9
	SD	3.3	3.8	3.6	7.0	2.3	2.6	5.4	3.5	3.8	1.9
J18	X	23	6	1	-1	1	4	3	4	0	9
	SD	3.1	5.8	3.0	2.8	6.2	5.6	4.8	3.2	3.0	3.1
J8	X	19	7	3	3	0	0	6	4	4	6
	SD	1.3	3.0	4.7	3.6	1.5	3.2	1.5	2.7	2.5	4.4
J23B	X	21	6	1	1	0	1	3	0	0	10
	SD	3.8	2.5	4.6	3.5	2.6	3.1	2.9	3.2	4.8	1.8
J17	X	20	9	2	3	3	5	3	2	3	5
	SD	1.8	3.0	3.0	3.0	2.8	2.3	2.8	3.6	3.2	2.8
J18B	X	20	8	3	-4	-2	1	1	3	4	3
	SD	3.2	2.9	3.4	4.5	3.3	7.0	7.1	1.7	4.8	3.3
	GM*	20.5	7.2	2.2	0.5	0.0	2.5	2.7	2.3	2.7	7.0
	SD	1.4	1.2	1.0	2.7	1.9	2.1	1.9	1.6	2.2	2.8

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (D) 100 Impulses at 139 dB:

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
E109	X	14	13	6	1	2	7	-	10	8	10
	SD	3.6	5.2	1.5	5.0	4.5	2.2	-	3.5	4.9	0.4
G30	X	24	7	6	-5	-2	2	0	-1	4	-1
	SD	4.6	3.3	3.9	4.9	4.0	3.0	4.3	5.1	8.8	4.0
E144	X	22	12	5	1	1	6	-	12	8	7
	SD	1.7	1.3	1.1	1.7	4.4	2.9	-	1.3	1.6	1.3
H16	X	24	11	-3	-3	3	4	1	3	2	4
	SD	3.6	0.9	3.1	6.9	4.8	3.1	3.4	7.4	1.5	4.3
H1	X	27	5	5	4	4	3	2	6	8	8
	SD	1.6	4.4	4.1	4.2	1.6	2.2	1.6	3.3	4.1	3.6
H42	X	23	4	-5	-4	-5	3	0	0	0	2
	SD	4.8	4.1	3.1	4.7	6.1	6.3	4.4	5.2	8.2	1.5
	GM*	22.3	8.7	1.5	-1.0	0.7	4.2		5.0	3.5	5.0
	SD	4.4	3.8	4.6	3.5	3.3	1.9		5.3	3.5	4.1

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (E) 1 Impulses at 147 dB:

Test Frequency (kHz)

Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
X15	X	23	9	-1	0	-2	0	2	1	4	8
	SD	2.5	5.4	2.3	4.5	3.4	5.5	2.1	1.0	4.6	4.8
J13	X	26	9	2	4	1	4	2	8	1	6
	SD	4.2	3.7	1.9	4.2	1.8	3.8	4.3	4.0	3.7	4.4
J15	X	22	8	1	3	2	3	0	5	-1	4
	SD	6.3	3.4	4.3	3.6	4.2	5.4	5.1	4.4	4.0	2.0
J21	X	25	9	3	1	1	6	1	8	6	6
	SD	3.1	2.3	1.3	3.3	3.0	3.8	3.8	4.0	2.4	5.2
J14A	X	28	6	3	1	2	8	5	5	2	4
	SD	4.4	1.0	7.3	2.4	4.7	3.3	3.9	3.2	11.8	8.0
J20A	X	24	8	1	-1	2	2	2	-1	7	6
	SD	5.5	5.5	4.1	4.4	9.3	9.0	5.5	4.3	2.6	9.6
	GM*	24.7	8.2	1.5	1.3	1.0	3.8	2.0	4.3	3.2	5.7
	SD	2.2	1.2	1.5	1.9	1.5	2.9	1.7	3.7	3.1	1.5

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (F) 10 Impulses at 147 dB:

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
X4	X	21	8	1	1	-2	3	2	0	1	3
	SD	1.3	4.5	4.0	3.3	3.4	6.8	3.5	4.0	1.9	5.2
J9	X	25	8	4	-1	-1	0	5	1	2	5
	SD	5.7	3.8	5.2	6.3	8.1	7.2	4.2	9.2	9.4	3.3
X3	X	24	8	1	5	2	7	3	10	7	7
	SD	2.0	3.1	6.1	1.1	1.9	2.3	3.7	5.8	3.6	4.0
J1	X	23	12	5	3	4	4	4	6	2	6
	SD	3.6	5.7	2.0	2.5	2.1	1.9	1.8	3.8	2.6	4.0
J4	X	25	9	3	0	3	5	3	7	2	5
	SD	2.4	3.5	4.5	3.4	1.7	2.5	3.6	4.6	2.2	4.2
G29	X	21	10	1	0	-2	2	-2	-1	-1	6
	SD	2.7	4.9	3.2	4.0	3.0	6.9	3.3	3.2	2.7	6.5
	GM*	23.2	9.2	2.5	1.3	0.7	3.5	2.5	3.8	2.2	5.3
	SD	1.8	1.6	1.8	2.3	2.7	2.4	2.4	4.4	2.6	1.4

GM* = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (G) 100 Impulses at 147 dB:

Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
		Test Frequency (kHz)									
G5	X	23	8	2	4	2	5	1	5	5	5
	SD	6.6	4.3	3.9	2.8	3.9	5.1	3.2	0.7	4.2	4.2
G20	X	25	12	2	3	3	4	1	4	4	4
	SD	2.4	5.9	5.0	4.4	7.5	4.4	8.6	7.1	5.4	5.1
G2	X	24	4	3	1	5	6	6	4	2	9
	SD	1.6	1.6	4.2	3.5	4.2	4.2	4.7	1.6	5.7	1.6
E138	X	18	9	1	-3	1	8	-	9	9	10
	SD	5.8	7.8	0.5	4.8	4.8	0.5	-	2.8	7.2	5.6
F1	X	19	7	0	-2	2	7	-	-1	5	8
	SD	1.6	4.8	3.5	1.6	3.5	1.6	-	1.6	3.5	4.2
E115	X	25	5	0	-2	3	5	-	0	2	0
	SD	4.0	5.4	1.8	6.0	3.2	5.5	-	3.7	2.6	4.4
	GM*	22.3	5.8	1.2	0.2	2.7	5.8		3.5	4.5	6.0
	SD	3.1	2.6	1.2	2.9	1.4	1.5		3.6	2.6	3.7

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAM (dB SPL) AND STANDARD DEVIATION (dB)
FOR ALL ANIMALS USED IN THIS STUDY

	Test Frequency (kHz)									
Group Means	.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
A	21.4	10.2	-1.6	-1.0	-1.4	0.6	2.4	-0.2	0.6	2.8
B	24.0	10.2	-0.2	2.2	0.2	2.2	3.0	1.5	1.8	4.2
C	20.5	7.2	2.2	0.5	0.0	2.5	2.7	2.3	2.7	7.0
D	22.3	8.7	1.5	-1.0	0.7	4.2		5.0	3.5	5.0
E	24.7	8.2	1.5	1.3	1.0	3.8	2.0	4.3	3.2	5.7
F	23.2	9.2	2.5	1.3	0.7	3.5	2.5	3.8	2.2	5.3
G	22.3	5.8	1.2	0.2	2.7	5.8		3.5	4.5	6.0
Mean	22.6	7.1	1.0	0.5	0.6	3.2		2.9	2.6	5.1
SD	1.5	3.3	1.4	1.2	1.2	1.7		1.8	1.3	1.3

APPENDIX B

Postexposure threshold shifts for each exposure group (A-G) and for individual animals in each group.

Permanent threshold shift (PTS) is the mean of the threshold shifts obtained on the last four postexposure days.

Average maximum threshold shift (TS) is calculated by taking the maximum threshold shift for each animal, irrespective of when in time it occurred, and averaging the maximum TS across the animals that constitute the particular exposure group.

Standard Deviation (SD) for all measures are presented when appropriate.

Group A - Postexposure threshold shifts

Animals: K7R*
J35R
K5R
J34R
K105R

*R refers to the right ear

**(See page B-3)
The group mean PTS and SD that are identified on each of the summary pages were calculated for each test frequency. These means and SDs were obtained by first summing the individual values of PTS from the last four postexposure tests for all animals in each group and then computing the mean and SDs.

Group A

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 131 dB 100 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
6	12	13	14	18	11	10	8	11	18	0.000
8	8	11	12	16	9	6	8	9	8	0.021
2	8	11	8	12	8	4	6	11	6	0.042
2	8	11	6	10	5	4	8	7	6	0.063
-5	2	9	13	5	7	6	2	1	5	0.125
-2	3	6	6	10	8	5	3	8	4	0.250
1	2	1	1	0	1	0	-2	7	5	1.000
3	3	4	5	1	0	3	-1	0	-3	2.000
0	-1	-2	2	2	4	-3	-1	4	0	6.000
-1	0	-3	2	1	-1	-6	0	5	1	9.000
0	6	-1	2	2	3	0	0	-3	4	13.000
-2	-4	8	2	0	4	-1	0	0	4	16.000
4	1	0	4	0	-4	-2	-3	2	6	20.000
0	-3	3	4	4	9	-3	8	9	4	23.000
2	-2	1	2	4	5	0	2	1	8	27.000
2	-2	2	4	4	2	-3	6	4	4	30.000
2	-1	1	4	3	3	-2	3	4	6	MEAN GROUP PTS** (dB)
3.9	2.8	4.1	5.0	7.4	7.0	6.4	7.0	5.3	5.1	SD GROUP PTS** (dB)
13	13	18	18	27	20	13	14	18	22	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
5.2	10.6	7.0	7.4	12.5	7.9	5.5	4.3	12.6	16.1	0.000
12.4	10.4	6.6	7.4	12.2	8.4	12.3	6.1	6.3	2.4	0.021
5.0	10.6	9.6	3.5	4.8	5.6	5.7	6.3	4.5	5.4	0.042
4.3	9.8	11.5	7.8	6.5	1.4	3.0	6.4	3.2	6.1	0.063
2.0	5.5	8.2	7.8	6.3	4.4	8.6	1.8	6.2	6.6	0.125
4.4	4.2	8.4	5.3	13.2	7.6	10.2	7.1	7.0	7.2	0.250
1.5	3.7	7.7	8.3	2.5	4.7	6.4	6.9	12.6	13.2	1.000
6.0	2.3	7.4	6.3	2.3	4.1	4.7	3.1	9.2	4.5	2.000
5.3	3.8	3.3	7.7	3.8	4.6	4.5	5.4	4.5	5.3	6.000
1.9	4.3	5.1	4.3	3.6	9.5	4.9	7.8	11.4	4.7	9.000
3.1	12.8	3.5	4.0	4.4	5.6	3.6	5.2	4.0	10.8	13.000
4.7	5.2	10.7	5.9	2.4	14.0	4.1	4.3	6.5	4.9	16.000
4.8	2.4	6.4	6.9	6.7	0.9	7.8	4.0	7.7	2.9	20.000
5.3	2.7	4.9	8.3	12.1	16.4	7.0	7.6	7.1	5.5	23.000
6.2	3.5	6.7	7.5	5.4	6.2	7.1	9.3	7.6	11.5	27.000
2.8	5.9	4.0	10.2	8.9	5.4	7.8	11.1	6.9	10.9	30.000

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA K7

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
3	17	7	3	21	13	17	1	11	13	0.000
1	5	5	1	19	21	25	9	-1	11	0.021
-1	13	13	9	7	9	13	-3	17	9	0.042
-3	11	11	-3	15	7	1	15	5	17	0.063
-3	1	11	17	5	7	21	5	5	7	0.125
-5	-1	-1	15	33	5	19	-6	3	-4	0.250
3	-3	-2	-7	1	3	-3	-9	1	-7	1.000
11	5	6	11	-1	1	5	-1	-11	-9	2.000
-1	-7	-7	-4	7	9	3	-3	7	-1	6.000
-1	3	3	-2	-3	-1	-7	-3	7	9	9.000
-3	1	3	7	5	7	1	-5	-5	7	13.000
1	-5	5	1	-1	1	5	-1	-1	11	16.000
7	1	-9	-3	-5	-3	-9	-5	5	7	20.000
2	-4	-4	2	10	2	-4	0	0	2	23.000
0	-6	-6	10	-4	0	4	-12	-2	0	27.000
-2	-8	2	8	-4	-2	-8	-4	-4	-2	30.000
2	-4	-4	4	-1	-1	-4	-6	0	2	PTS (dB)
11	17	13	17	33	21	25	15	17	17	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA J35

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
5	7	7	17	13	-1	7	9	3	9	0.000
3	5	7	15	11	-3	-5	7	11	7	0.021
1	3	3	13	19	2	3	5	9	5	0.042
-1	1	1	11	17	3	1	3	7	3	0.063
-3	9	-1	9	15	11	-1	1	5	11	0.125
4	6	-4	6	2	8	-4	-2	12	-2	0.250
2	4	-6	14	0	-4	-6	-4	0	-4	1.000
2	4	-6	4	0	-4	4	-4	0	-4	2.000
0	1	1	1	-3	3	-9	-7	7	-7	6.000
-3	-1	-1	-1	5	-9	-1	-9	5	1	9.000
4	-4	-4	6	2	-2	-4	-2	2	-2	13.000
4	-4	-4	-4	2	-2	-4	-2	12	-2	16.000
1	3	3	13	-1	-5	-7	-5	-1	8	20.000
-1	1	1	1	-3	-7	-9	3	7	3	23.000
7	-1	-1	-1	5	1	-11	1	-5	1	27.000
5	7	-3	-3	3	-1	-13	-1	3	-1	30.000
3	3	0	3	1	-3	-10	-1	1	3	PTS (dB)
9	9	7	17	19	11	7	9	12	11	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA K5

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
1	5	11	13	3	11	9	11	11	11	0.000
-1	3	9	11	11	9	-3	9	9	9	0.021
7	1	17	9	9	7	5	7	7	7	0.042
5	9	5	7	7	5	3	5	5	5	0.063
-7	7	3	5	5	3	1	3	3	3	0.125
0	4	10	2	2	0	-2	10	0	10	0.250
0	4	0	2	2	0	-2	0	0	0	1.000
-1	3	9	1	1	-1	-3	-1	-1	-1	2.000
-3	1	-3	-5	-1	-3	-5	7	-3	-3	6.000
0	4	0	2	2	0	-2	0	0	0	9.000
-2	2	-2	0	0	-2	-4	-2	-2	-2	13.000
-3	1	7	-1	-1	-3	-5	-3	-3	7	16.000
-3	1	-3	-1	-1	-3	-5	-3	-3	7	20.000
-5	-4	5	-3	-3	5	-7	5	5	5	23.000
-7	-3	3	-5	5	3	1	3	3	3	27.000
1	-5	1	-7	3	1	-1	1	1	1	30.000
-4	-3	1	-4	1	1	-3	1	1	4	PTS (dB)
7	9	17	13	11	11	9	11	11	11	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA J34

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
11	3	23	17	37	21	13	11	31	47	0.000
29	1	21	15	5	9	1	-1	9	5	0.021
-3	-1	-1	3	13	17	-1	7	7	13	0.042
5	-3	7	1	1	5	7	15	5	1	0.063
-7	-5	15	9	-1	3	5	3	3	9	0.125
-3	-1	9	3	3	7	-1	7	17	3	0.250
-1	1	1	-5	3	-1	1	9	29	25	1.000
-3	-1	-1	13	3	-3	-1	-3	-3	3	2.000
-3	-1	-1	13	3	7	-1	-3	7	3	6.000
1	-7	-7	7	-3	-9	-7	1	-9	-3	9.000
1	3	3	-3	-3	1	3	1	-9	-3	13.000
-3	-1	9	3	3	-3	-1	7	-3	3	16.000
5	-2	7	1	11	-5	7	-5	-5	1	20.000
-3	-1	9	3	23	7	-1	17	17	13	23.000
5	-3	-3	11	11	5	-3	5	-5	11	27.000
3	-5	5	19	19	3	5	23	13	-1	30.000
3	-3	5	9	16	3	2	10	5	6	PTS (dB)
29	3	23	19	37	21	13	23	31	47	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA K105

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
13	28	16	22	18	10	3	8	-2	12	0.000
11	26	14	20	36	8	11	16	16	10	0.021
9	24	22	8	14	6	-1	14	14	-2	0.042
7	22	30	16	12	4	7	2	12	6	0.063
-5	0	18	24	0	12	5	0	-10	-6	0.125
-7	8	16	2	8	20	13	8	8	12	0.250
1	6	14	0	-4	8	11	-4	6	10	1.000
9	4	12	-2	4	6	9	4	14	-2	2.000
-3	2	0	6	2	4	-3	2	2	6	6.000
-3	2	-10	6	2	14	-13	12	22	-3	9.000
3	28	4	2	8	10	3	8	-2	22	13.000
-8	-13	25	11	-3	29	2	-3	-3	1	16.000
9	4	2	8	-6	-4	7	4	14	8	20.000
9	-6	2	18	-6	36	9	14	14	-2	23.000
8	3	11	-3	3	15	8	13	13	27	27.000
4	-1	7	3	-1	11	4	9	9	23	30.000
7	0	6	7	-2	15	7	10	13	14	PTS (dB)
13	28	30	24	36	36	13	16	22	27	MAXIMUM TS (dB)

Group B - Postexposure threshold shifts

Animals: K68R*
K116R
K103R
H184R
K108R
K21R

*R refers to the right ear

Group B

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 135 dB 100 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
15	23	26	34	44	33	30	26	23	19	0.000
18	20	24	32	34	35	28	31	28	28	0.021
18	20	31	33	33	35	30	29	23	33	0.042
14	20	28	25	31	38	25	31	32	21	0.063
16	27	24	25	28	31	26	21	26	21	0.125
17	28	23	27	24	27	26	22	25	19	0.250
17	24	25	26	24	30	29	22	15	19	1.000
11	12	21	19	17	19	12	20	8	12	2.000
7	8	22	18	15	16	15	17	11	6	6.000
4	6	8	16	9	13	14	10	10	7	9.000
5	12	13	7	9	12	9	10	7	9	13.000
5	5	12	3	8	7	8	7	4	4	16.000
3	8	11	9	12	7	7	3	3	4	20.000
4	4	10	6	7	10	10	8	9	2	23.000
0	4	8	9	5	7	12	5	3	7	27.000
1	1	10	10	8	8	3	7	4	8	30.000
2	4	10	8	8	8	8	6	5	5	MEAN GROUP PTS (dB)
5.0	4.6	10.1	9.5	9.8	10.5	10.5	6.1	5.5	4.1	SD GROUP PTS (dB)
29	39	41	43	50	47	45	44	42	39	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
10.7	13.6	18.4	14.1	13.4	19.6	16.9	14.8	17.3	12.3	0.000
9.4	13.2	11.5	15.7	18.4	18.4	14.9	13.3	17.4	8.1	0.021
18.1	19.4	21.4	20.1	20.4	17.3	15.6	13.0	15.9	13.4	0.042
9.3	15.5	23.5	20.9	18.3	18.1	17.3	17.8	18.6	17.8	0.063
22.0	26.5	22.5	19.2	24.0	19.8	24.3	16.7	14.7	12.7	0.125
15.9	26.3	27.3	23.1	20.8	25.7	23.1	20.9	24.5	20.9	0.250
11.3	20.3	19.1	23.9	20.6	30.4	26.2	22.8	15.9	17.6	1.000
9.1	13.7	20.5	17.4	9.7	21.4	11.3	19.0	11.4	10.1	2.000
4.5	4.3	14.7	19.2	15.5	13.9	11.3	16.9	14.4	7.5	6.000
7.9	10.1	13.2	18.0	12.4	13.7	18.2	14.3	14.3	12.9	9.000
8.0	15.4	20.0	15.3	11.0	14.7	19.5	11.2	8.4	21.6	13.000
3.0	6.9	13.8	7.1	11.7	11.3	9.0	8.8	8.1	7.8	16.000
7.8	14.8	17.0	11.9	17.7	16.2	13.6	5.3	1.6	11.8	20.000
7.7	9.2	8.6	11.8	9.3	14.9	13.6	9.5	14.8	4.4	23.000
3.2	4.3	7.4	13.5	9.6	9.1	17.3	7.2	3.1	7.9	27.000
4.9	6.2	11.8	9.9	6.7	8.7	6.2	8.5	7.7	6.5	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H184

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
26	26	44	40	44	40	42	30	38	30	0.000
14	14	22	38	53	38	40	38	36	28	0.021
12	2	20	26	33	26	18	26	34	26	0.042
10	10	18	24	28	34	26	34	36	24	0.063
8	8	16	22	16	12	24	12	10	12	0.125
5	5	3	9	13	-1	11	-1	-3	9	0.250
3	3	13	7	1	-3	9	-3	-5	7	1.000
-1	-1	7	3	7	-7	5	3	-9	3	2.000
5	5	13	-1	3	-1	11	-1	-3	-1	6.000
0	0	8	4	8	1	6	4	2	4	9.000
4	4	2	-2	12	-2	0	-2	6	-2	13.000
4	4	12	-2	2	-2	10	-2	-4	-2	16.000
2	2	0	6	0	-4	-2	-4	4	-4	20.000
1	1	9	5	-1	-5	-3	5	3	5	23.000
-1	-1	7	3	-3	3	5	3	1	3	27.000
-3	-3	5	1	5	1	3	1	-1	1	30.000
-1	-1	5	3	0	-2	0	1	2	1	PTS (dB)
26	26	44	40	53	40	42	38	38	30	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K21

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
10	27	9	27	55	13	33	18	15	-3	0.000
8	7	17	15	13	11	19	15	13	15	0.021
16	15	25	13	9	39	39	33	11	43	0.042
14	23	13	11	9	27	7	51	31	1	0.063
12	11	11	19	7	25	25	29	27	19	0.125
20	19	19	17	25	25	23	7	25	7	0.250
28	27	27	25	33	38	11	5	23	15	1.000
24	3	13	21	19	24	7	21	9	11	2.000
3	12	32	20	18	16	16	30	18	10	6.000
-4	5	-5	13	1	9	9	3	31	-7	9.000
-6	3	3	1	-1	-3	7	1	-1	-9	13.000
3	2	2	10	-2	6	-4	10	8	0	16.000
10	-1	9	7	5	3	13	7	5	-3	20.000
2	21	11	9	7	35	15	19	37	9	23.000
0	9	-1	-3	5	3	3	7	5	17	27.000
10	-1	9	17	15	13	13	7	5	17	30.000
5	7	7	8	8	14	11	10	13	10	PTS (dB)
28	27	32	27	55	39	39	51	37	43	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K108

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
28	40	44	56	50	58	48	38	50	30	0.000
36	40	42	54	48	56	46	36	48	38	0.021
54	58	70	62	56	64	54	54	46	56	0.042
32	46	68	60	54	62	52	52	64	54	0.063
60	74	66	58	62	60	70	50	52	42	0.125
48	62	64	66	60	68	58	48	60	50	0.250
17	51	33	35	19	37	57	37	9	9	1.000
17	21	33	35	19	27	17	27	9	9	2.000
13	7	29	21	15	33	23	23	5	5	6.000
7	11	13	15	19	27	17	27	9	19	9.000
17	31	33	15	19	27	-3	27	19	49	13.000
4	8	20	12	16	24	14	4	-4	6	16.000
11	15	17	9	13	21	11	1	3	3	20.000
19	3	15	27	11	19	22	9	11	1	23.000
5	9	21	23	7	15	45	15	7	17	27.000
3	7	19	21	15	13	3	23	15	15	30.000
9	8	18	20	11	17	20	12	9	9	PTS (dB)
60	74	70	66	62	68	70	54	64	56	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K103

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
17	33	41	39	43	41	7	9	3	15	0.000
16	32	30	28	22	40	16	38	12	34	0.021
5	21	43	37	31	29	15	17	1	23	0.042
14	10	44	36	40	48	24	16	20	22	0.063
3	29	17	25	39	37	23	5	19	31	0.125
12	58	46	44	18	46	42	44	48	40	0.250
31	37	55	63	57	75	61	53	37	49	1.000
10	36	54	32	26	54	30	32	16	28	2.000
9	15	43	52	35	23	29	41	35	17	6.000
18	24	32	50	24	32	48	30	24	26	9.000
8	34	42	30	24	32	48	20	14	16	13.000
11	17	35	3	27	5	21	23	17	19	16.000
-11	35	43	31	45	33	29	11	5	27	20.000
-2	-6	22	0	24	12	28	20	4	-4	23.000
-3	3	11	29	23	21	17	9	3	5	27.000
-4	8	30	18	12	20	5	8	12	4	30.000
-5	10	26	19	26	22	20	12	6	8	PTS (dB)
31	58	55	63	57	75	61	53	48	49	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K68

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
0	4	8	24	52	42	41	48	18	24	0.000
18	22	26	42	50	50	39	46	46	32	0.021
6	10	14	50	58	38	37	24	24	30	0.042
4	28	22	18	46	46	35	22	32	18	0.063
12	36	30	26	44	44	23	20	30	16	0.125
9	23	17	23	31	21	30	27	17	13	0.250
17	31	25	31	29	39	38	35	25	31	1.000
15	9	23	29	27	17	16	43	23	19	2.000
3	7	11	17	25	25	14	11	11	-3	6.000
1	-5	-1	15	13	13	12	-1	-1	-5	9.000
-1	3	7	13	1	11	0	7	-3	-7	13.000
5	-1	3	-1	-3	17	6	3	3	-1	16.000
3	-3	1	7	15	-5	4	1	1	-3	20.000
-2	2	6	2	0	0	-1	-4	-4	2	23.000
-4	0	4	0	-2	-2	7	-6	4	0	27.000
0	4	-2	4	2	2	1	-2	-2	4	30.000
-1	1	2	3	4	-1	3	-3	0	1	PTS (dB)
18	36	30	50	58	50	41	48	46	32	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K116

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
8	10	10	16	18	6	12	16	14	16	0.000
16	8	8	14	16	14	10	14	12	24	0.021
14	16	16	12	14	12	18	22	20	22	0.042
12	4	4	0	12	10	6	10	8	10	0.063
0	2	2	-2	0	8	-6	8	16	8	0.125
8	0	-10	6	-2	6	-8	6	4	-4	0.250
6	-2	-2	-6	6	-6	0	4	2	4	1.000
4	6	-4	-8	4	2	-2	-8	0	2	2.000
12	4	5	0	-8	0	-4	0	-2	9	6.000
0	2	2	-2	-10	-2	-6	-2	-4	8	9.000
8	0	-10	-14	-2	6	2	6	4	6	13.000
6	-2	-2	-6	6	-6	0	4	2	4	16.000
6	-2	-2	-6	-4	-6	-10	4	2	4	20.000
4	6	-4	-8	4	2	-2	2	0	2	23.000
2	4	4	0	2	0	-4	0	-2	0	27.000
0	-8	2	-2	0	-2	-6	8	-4	8	30.000
3	0	0	-4	1	-2	-6	4	-1	4	PTS (dB)
16	16	16	16	18	14	18	22	20	24	MAXIMUM TS (dB)

Group C - Postexposure threshold shifts

Animals: J10R*
J18R
J8R
J23BR
J17R
J18BR

*R refers to the right ear

Group C

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 139 dB 10 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
10	11	12	17	23	17	14	14	15	6	0.000
7	10	15	18	29	21	25	17	17	13	0.021
7	19	14	14	19	16	12	18	22	19	0.042
9	17	19	17	18	18	19	14	19	17	0.063
12	19	20	28	22	17	22	15	21	18	0.125
13	6	18	12	15	8	17	15	14	17	0.250
5	8	8	9	10	5	9	7	10	5	1.000
2	3	4	6	1	13	2	6	8	14	2.000
6	4	5	3	6	6	6	6	4	5	6.000
2	5	3	5	4	2	8	4	9	5	9.000
4	0	4	5	6	5	4	7	6	7	13.000
3	1	-1	4	5	4	6	3	6	6	16.000
3	-1	1	1	5	2	6	4	10	4	20.000
3	-1	3	2	5	5	4	7	10	7	23.000
3	1	-1	3	1	3	2	7	1	4	27.000
2	0	2	7	7	5	2	7	7	1	30.000
3	0	1	3	4	4	4	6	7	4	MEAN GROUP PTS (dB)
5.3	5.2	3.3	5.6	4.8	4.0	5.2	6.2	6.1	7.8	SD GROUP PTS (dB)
15	26	27	30	31	25	31	25	28	28	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
8.6	8.3	7.4	12.8	23.5	16.0	10.2	9.6	11.1	6.7	0.000
5.6	7.9	16.5	15.5	24.1	15.0	21.5	14.9	15.2	16.6	0.021
11.9	19.4	17.1	18.5	21.7	12.2	8.7	19.0	24.1	15.1	0.042
11.8	23.5	19.6	19.9	24.8	14.7	22.7	21.8	17.9	20.8	0.063
10.9	24.2	24.7	28.5	26.5	17.8	18.6	17.2	24.3	16.5	0.125
14.1	14.0	20.3	8.8	12.7	5.2	5.0	6.0	4.3	15.7	0.250
5.1	7.7	8.4	10.2	9.9	4.0	7.3	8.4	9.1	4.7	1.000
5.9	8.7	5.0	4.8	5.7	18.3	10.9	4.7	12.0	15.0	2.000
5.3	9.3	9.2	6.5	3.6	11.5	15.6	8.8	5.1	6.6	6.000
4.0	10.4	2.7	9.4	5.8	3.1	14.6	6.6	8.5	8.2	9.000
5.2	4.1	7.4	4.7	9.2	9.3	8.4	8.7	12.3	9.8	13.000
5.1	6.7	4.5	4.3	4.9	4.1	6.3	3.0	14.3	7.8	16.000
5.3	7.4	5.1	3.7	8.0	3.2	6.2	7.5	9.6	11.6	20.000
6.5	7.2	5.3	4.8	5.9	6.3	8.2	6.4	9.0	12.7	23.000
6.4	5.2	4.6	6.4	4.6	7.3	4.2	6.9	3.2	6.4	27.000
5.2	4.4	6.5	8.7	6.4	4.9	6.6	7.0	7.0	5.9	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J10

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
22	17	21	41	71	30	33	29	30	2	0.000
12	18	12	49	71	49	52	45	33	30	0.021
30	39	47	51	63	32	27	51	64	47	0.042
26	64	56	57	68	45	61	56	52	56	0.063
31	58	67	72	65	41	57	50	66	39	0.125
40	31	38	29	40	9	22	8	19	14	0.250
1	21	20	23	24	8	9	4	6	8	1.000
12	17	10	12	12	40	7	10	2	18	2.000
11	7	14	15	5	1	37	8	3	9	6.000
6	9	-2	23	14	7	17	12	22	12	9.000
8	1	-2	13	12	-2	3	19	0	8	13.000
9	9	-5	9	14	8	10	4	2	10	16.000
8	-2	10	6	21	-2	7	9	25	-2	20.000
10	5	2	8	14	8	16	14	23	10	23.000
12	3	-2	13	4	12	3	11	2	10	27.000
2	0	2	17	11	9	9	17	8	-5	30.000
8	1	3	11	12	7	9	13	15	3	PTS (dB)
40	64	67	72	71	49	61	56	66	56	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J18

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
18	24	18	7	15	44	14	4	19	2	0.000
14	21	47	16	43	25	51	3	39	38	0.021
7	46	2	12	10	29	14	25	37	28	0.042
20	15	24	17	13	23	28	14	21	22	0.063
20	40	30	55	46	37	28	5	29	40	0.125
16	5	49	8	15	17	15	25	17	46	0.250
11	14	15	15	9	11	19	21	26	-3	1.000
7	4	8	9	2	33	20	13	32	42	2.000
15	22	20	4	4	29	4	18	8	16	6.000
6	23	6	4	4	0	32	3	16	16	9.000
13	7	19	8	22	23	19	16	28	25	13.000
10	6	-4	9	8	5	16	3	31	12	16.000
9	13	-1	4	2	0	18	13	16	24	20.000
11	8	8	8	4	13	9	15	20	32	23.000
10	7	6	9	9	3	4	16	3	13	27.000
12	7	14	17	17	12	9	15	20	7	30.000
11	8	6	10	8	7	10	15	15	19	PTS (dB)
20	46	49	55	46	44	51	25	39	46	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J8

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
11	11	15	21	12	8	14	10	9	2	0.000
4	10	15	9	27	21	24	9	12	1	0.021
9	16	13	4	16	12	16	6	13	12	0.042
4	8	6	7	14	18	12	-4	2	16	0.063
6	13	8	11	2	9	14	6	2	12	0.125
9	5	0	4	13	6	19	14	7	6	0.250
12	1	9	11	7	5	5	9	15	9	1.000
-1	10	-1	0	-4	2	-10	4	6	10	2.000
3	-3	0	0	6	7	1	-1	4	6	6.000
-3	2	4	-4	1	2	-9	6	4	0	9.000
1	-5	5	2	-1	5	-7	-2	3	8	13.000
3	1	2	0	5	3	-1	5	10	15	16.000
-1	-3	-2	-4	-1	1	5	0	7	7	20.000
5	-5	6	-2	5	-3	-7	3	5	-1	23.000
1	6	0	3	-2	0	-6	2	-2	1	27.000
0	1	5	1	2	-1	-8	3	0	0	30.000
1	-1	3	-1	1	-1	-4	2	2	2	PTS (dB)
12	16	15	21	27	21	24	14	15	16	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J23B

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
3	4	4	13	12	10	6	19	5	17	0.000
-2	3	7	11	14	11	6	12	5	6	0.021
0	3	6	5	10	15	4	18	2	9	0.042
0	9	5	9	6	9	5	11	14	5	0.063
9	9	5	8	7	5	12	14	11	3	0.125
9	12	10	12	6	11	9	14	12	3	0.250
3	4	2	-1	-1	1	15	12	6	3	1.000
-3	-2	2	3	-1	-1	-2	3	4	3	2.000
4	-1	1	2	6	0	-5	12	7	1	6.000
-1	5	4	2	4	3	-2	5	2	-6	9.000
-1	-1	4	2	6	1	2	6	8	-2	13.000
1	1	7	0	-1	7	4	6	3	-5	16.000
5	0	-4	3	0	7	2	10	8	-5	20.000
-3	1	0	2	4	9	6	1	2	1	23.000
-2	-3	0	-2	-1	10	4	7	5	-5	27.000
1	-6	-3	7	9	3	2	4	6	-6	30.000
0	-2	-2	3	3	7	3	5	5	-4	PTS (dB)
9	12	10	13	14	15	15	19	14	17	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J17

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
4	11	5	7	9	7	15	18	23	2	0.000
6	5	13	8	6	12	10	12	8	1	0.021
1	11	12	3	8	5	9	13	13	10	0.042
5	0	11	8	3	6	11	11	16	8	0.063
2	1	6	6	6	9	17	12	12	10	0.125
5	-5	10	9	8	4	16	18	14	21	0.250
3	3	-1	-5	1	2	-2	-1	4	7	1.000
1	-1	-3	3	-4	0	2	6	4	8	2.000
2	1	-2	-5	1	2	3	5	8	-2	6.000
3	-6	4	0	-4	-1	5	5	3	2	9.000
2	0	1	0	-4	-2	4	1	3	6	13.000
-2	1	-1	1	3	5	4	-2	-1	3	16.000
-2	-5	0	-1	3	4	5	-4	0	9	20.000
-4	-3	9	-3	-4	-1	0	10	5	4	23.000
-3	1	-2	-3	-4	-1	0	9	1	3	27.000
-3	4	-4	-5	-1	4	4	7	4	4	30.000
-3	-1	1	-3	-2	1	3	5	3	5	PTS (dB)
6	11	13	9	9	12	17	18	23	21	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J18B

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
1	1	6	11	21	5	4	5	2	13	0.000
8	2	-2	13	14	10	7	21	5	1	0.021
-3	-2	2	7	7	3	4	-4	4	11	0.042
-4	7	9	5	4	9	-2	-2	6	-3	0.063
6	-4	6	13	6	-1	5	7	4	7	0.125
0	-8	1	9	7	3	22	11	13	11	0.250
1	8	1	8	20	2	7	0	3	9	1.000
-2	-7	5	10	0	6	-7	1	1	2	2.000
3	-1	-2	3	12	-2	-4	-6	-5	1	6.000
-2	-4	1	7	6	1	5	-8	4	9	9.000
2	-3	-1	5	4	7	2	2	-8	-1	13.000
-1	-11	-4	3	4	-3	1	1	-11	0	16.000
-3	-9	3	0	4	1	1	-3	1	-6	20.000
-1	-12	-5	0	9	2	-2	2	7	-1	23.000
-1	-7	-9	-1	-1	-7	6	-3	-3	5	27.000
0	-2	0	5	4	1	-2	0	6	7	30.000
-2	-8	-2	1	4	-1	1	-1	3	1	PTS (dB)
8	8	9	13	21	10	22	21	13	13	MAXIMUM TS (dB)

Group D - Postexposure threshold shifts

Animals: E109R*
G30R
E144R
H16R
H1
H42R

*R refers to the right ear

Group D

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 139 dB 100 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
47	57	58	53	58	67		43	37	29	0.000
42	60	66	58	63	64		54	58	44	0.021
55	61	75	75	68	73		63	60	46	0.042
48	65	73	73	70	75		61	65	50	0.063
49	68	75	68	68	77		65	64	46	0.125
43	57	65	66	64	73		55	56	50	0.250
37	44	57	48	56	57		51	46	31	1.000
26	52	54	45	39	48		39	32	24	2.000
23	36	41	39	49	41		24	31	20	6.000
27	28	35	41	38	39		34	24	22	9.000
12	27	34	33	27	34		21	24	12	13.000
12	27	29	31	29	40		18	24	21	16.000
17	28	26	27	24	35		16	14	14	20.000
13	27	31	21	24	27		17	17	11	23.000
10	26	24	26	29	29		17	21	13	27.000
13	22	27	25	27	25		13	19	16	30.000
13	26	27	25	26	29		16	18	14	MEAN GROUP PTS (dB)
6.0	9.1	8.6	7.0	11.1	13.9	0.0	5.2	10.2	13.1	SD GROUP PTS (dB)
62	75	85	80	76	83		69	72	57	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
9.5	16.1	11.3	21.3	13.7	11.1		10.1	13.9	5.4	0.000
13.3	16.5	16.7	10.2	8.3	14.3		22.4	19.9	19.8	0.021
9.0	20.4	17.6	15.7	7.3	18.1		15.4	22.1	19.9	0.042
17.6	21.3	16.1	19.7	13.7	17.9		13.0	19.7	15.9	0.063
14.3	21.3	12.6	17.2	10.3	13.2		12.9	14.5	16.9	0.125
4.8	11.2	10.1	11.6	8.1	3.5		10.1	11.9	13.6	0.250
11.7	7.8	10.3	14.7	14.3	5.8		8.3	15.4	10.5	1.000
16.6	8.6	7.8	10.8	11.7	14.8		20.2	15.3	16.4	2.000
12.5	11.1	8.6	12.6	9.8	13.5		15.6	18.7	15.0	6.000
10.4	9.4	8.3	9.8	10.8	14.4		15.9	9.0	13.4	9.000
10.5	13.0	13.0	16.3	11.2	18.2		12.9	12.8	12.4	13.000
5.9	14.5	9.7	12.7	8.9	19.6		10.5	13.0	16.2	16.000
8.4	15.1	14.7	12.8	14.4	23.9		9.6	12.0	18.4	20.000
9.9	11.5	11.2	10.4	10.8	13.7		5.3	9.4	13.0	23.000
8.1	7.7	20.5	7.2	18.0	15.6		6.3	13.7	12.9	27.000
10.0	7.7	9.9	5.7	9.9	13.4		6.4	15.8	14.7	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E109

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
40	31	50	53	55	49		31	32	20	0.000
30	31	40	43	55	39		31	22	10	0.021
40	31	40	53	55	49		41	22	10	0.042
40	32	50	53	55	49		41	31	20	0.063
45	31	63	61	64	64		44	52	17	0.125
43	56	60	63	65	69		51	42	40	0.250
60	52	50	53	45	49		41	23	18	1.000
40	42	40	33	35	29		11	11	0	2.000
40	42	50	43	55	49		11	23	8	6.000
35	36	26	47	42	30		29	25	34	9.000
28	19	19	10	15	3		22	8	7	13.000
18	5	15	24	17	21		24	26	11	16.000
12	19	9	28	21	15		2	8	7	20.000
12	10	19	8	21	5		9	11	6	23.000
12	20	9	18	11	5		9	11	6	27.000
16	13	13	21	14	9		12	14	9	30.000
13	16	13	19	17	9		8	11	7	PTS (dB)
60	56	63	63	65	69		51	52	40	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G30

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
62	73	56	65	51	64		37	27	28	0.000
48	64	56	71	57	81		72	71	57	0.021
56	57	74	79	70	68		68	58	50	0.042
55	70	68	86	64	72		60	76	64	0.063
46	58	66	86	76	62		76	46	67	0.125
48	55	79	76	69	78		73	62	68	0.250
36	47	41	65	72	62		57	52	30	1.000
29	52	59	57	48	66		40	31	15	2.000
36	35	41	62	61	47		39	47	32	6.000
32	25	49	56	52	60		62	22	30	9.000
19	50	45	54	45	51		40	41	27	13.000
15	43	35	56	39	68		26	43	51	16.000
6	37	49	49	48	61		21	6	41	20.000
16	40	31	35	38	27		23	13	5	23.000
9	27	-4	37	37	44		24	34	18	27.000
17	16	40	26	41	29		19	33	37	30.000
12	30	29	37	41	40		22	22	25	PTS (dB)
62	73	79	86	76	81		76	76	68	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E144

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
41	71	41	11	36	75		61	59	31	0.000
60	61	90	50	55	74		80	79	60	0.021
59	79	89	102	74	103		79	87	67	0.042
58	83	78	100	75	101		68	84	58	0.063
51	88	71	71	76	95		71	87	51	0.125
41	51	71	61	66	75		51	59	51	0.250
30	30	60	30	35	54		60	68	35	1.000
19	49	49	49	34	63		59	57	39	2.000
18	33	28	28	33	52		38	56	38	6.000
7	17	27	37	32	51		17	35	37	9.000
6	16	16	26	21	40		16	34	16	13.000
15	25	25	25	20	39		15	33	15	16.000
14	34	24	24	19	48		14	32	26	20.000
23	33	33	23	18	47		13	31	33	23.000
12	32	42	32	57	46		22	40	32	27.000
21	31	31	31	36	45		21	39	31	30.000
17	32	33	27	33	47		17	36	30	PTS (dB)
60	88	90	102	76	103		80	87	67	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H16

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
50	65	72	58	69	80		45	35	37	0.000
23	67	68	59	67	61		24	53	34	0.021
67	43	78	72	64	65		46	53	38	0.042
18	47	64	48	56	64		51	62	47	0.063
26	68	98	40	56	85		62	71	41	0.125
47	41	66	48	55	73		44	40	30	0.250
31	42	70	33	63	54		45	44	47	1.000
-4	43	61	52	20	41		17	28	13	2.000
14	15	39	33	53	16		28	27	2	6.000
29	18	32	43	20	23		29	23	7	9.000
7	17	44	48	26	25		1	12	-3	13.000
4	25	36	23	29	59		25	11	22	16.000
29	1	19	15	15	57		9	4	-7	20.000
-5	16	25	10	14	21		18	27	8	23.000
-4	13	20	21	16	18		10	10	6	27.000
-5	20	18	34	24	29		9	-5	0	30.000
4	13	21	20	17	31		11	9	2	PTS (dB)
67	68	98	72	69	85		62	71	47	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H1

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
38	51	66	66	73	72		46	47	31	0.000
47	80	72	61	72	65		63	60	61	0.021
57	74	84	73	69	74		68	65	58	0.042
69	86	83	77	87	78		69	59	60	0.063
70	87	70	64	57	70		58	62	44	0.125
35	63	66	71	55	75		58	66	53	0.250
28	41	56	46	53	56		44	38	36	1.000
39	58	58	47	48	53		48	28	36	2.000
19	48	35	39	42	37		29	28	31	6.000
27	36	38	32	42	41		41	29	20	9.000
-2	31	35	36	35	51		25	21	25	13.000
15	43	22	26	37	33		22	24	20	16.000
19	40	38	32	34	23		25	26	22	20.000
12	32	24	27	37	30		22	12	20	23.000
12	31	24	26	37	31		20	21	21	27.000
7	31	32	21	27	26		13	15	16	30.000
13	34	30	27	34	27		20	19	20	PTS (dB)
70	87	84	77	87	78		69	66	61	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H42

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
53	49	64	64	67	62		40	21	30	0.000
43	54	67	64	73	63		54	60	45	0.021
53	80	81	72	75	82		74	72	53	0.042
46	73	96	73	83	86		77	80	53	0.063
53	73	78	85	79	84		79	67	56	0.125
45	74	49	79	76	70		53	65	59	0.250
38	48	64	62	70	65		58	53	21	1.000
34	64	55	30	51	38		57	39	39	2.000
8	35	50	30	48	48		0	3	12	6.000
33	37	35	30	39	29		26	8	7	9.000
13	28	44	25	18	36		21	26	2	13.000
4	22	41	32	35	21		-1	9	5	16.000
23	37	17	15	8	4		27	8	-2	20.000
21	32	51	22	15	31		19	8	-4	23.000
21	32	51	22	15	31		19	8	-4	27.000
21	18	25	20	21	11		4	15	6	30.000
22	30	36	20	14	19		17	10	-1	PTS (dB)
53	80	96	85	83	86		79	80	59	MAXIMUM TS (dB)

Group E - Postexposure threshold shifts

Animals: X15R*
J13R
J15R
J21R
J14AR
J20AR

*R refers to the right ear

Group E

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 147 dB 1 IMPULSE

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
0	16	27	16	23	15	21	14	11	12	0.000
4	22	14	12	10	14	21	22	17	25	0.021
8	18	17	16	8	14	22	16	12	17	0.042
10	17	19	14	9	25	24	18	15	28	0.063
7	13	19	14	10	20	18	16	16	16	0.125
5	11	12	16	12	19	16	15	15	24	0.250
0	1	13	7	8	3	7	3	2	3	1.000
-1	6	12	9	11	2	11	6	12	16	2.000
-1	1	3	3	4	0	7	3	3	4	6.000
0	1	-2	4	0	-3	7	1	1	1	9.000
-2	2	0	-1	1	-1	1	3	2	0	13.000
-2	3	-1	3	2	4	2	0	5	1	16.000
-2	-1	0	0	3	-1	3	0	3	3	20.000
0	2	2	2	1	-2	4	-4	1	2	23.000
-1	2	1	0	2	0	3	-1	0	5	27.000
-2	2	2	1	2	1	5	-2	0	4	30.000
-1	2	1	1	2	0	4	-1	1	3	MEAN GROUP PTS (dB)
3.0	4.5	2.6	3.4	2.8	2.7	3.8	4.4	3.4	3.8	SD GROUP PTS (dB)
16	27	35	27	26	30	31	30	31	34	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
8.7	22.7	12.8	10.7	15.8	6.3	9.1	14.3	17.9	11.3	0.000
8.1	22.0	23.6	3.0	13.1	10.1	16.1	17.6	11.7	15.4	0.021
6.5	17.8	8.9	9.6	6.0	7.2	16.7	16.5	15.7	9.0	0.042
12.1	22.1	11.7	12.7	7.0	21.9	17.2	18.3	11.8	20.3	0.063
10.9	16.0	19.4	16.4	10.0	17.5	11.3	22.9	13.5	6.9	0.125
10.0	12.8	12.8	6.6	12.0	18.0	8.5	12.5	16.0	26.6	0.250
6.2	5.2	15.2	6.7	11.1	8.1	5.0	8.8	9.0	8.2	1.000
4.9	13.2	9.4	8.6	9.2	5.7	9.1	9.6	18.6	19.1	2.000
5.2	3.2	5.5	4.4	3.9	2.2	2.8	11.3	5.1	1.9	6.000
3.2	7.0	7.3	6.7	4.9	3.8	7.3	6.5	5.6	7.9	9.000
2.7	4.4	4.9	3.9	3.7	4.4	7.0	4.9	3.2	5.1	13.000
6.0	6.2	5.4	3.1	3.7	5.2	4.5	6.1	6.6	6.4	16.000
4.0	3.9	6.1	6.3	4.3	4.1	4.5	4.5	3.8	5.6	20.000
3.7	3.7	6.2	9.1	5.5	3.1	8.7	5.3	5.3	6.0	23.000
5.2	4.6	4.3	4.0	4.6	3.4	5.7	5.0	5.7	6.4	27.000
6.4	9.0	3.9	4.1	5.2	8.2	5.1	8.0	5.4	3.2	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA X15

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
-2	8	23	19	51	13	22	8	-1	2	0.000
18	41	5	12	23	4	43	26	31	39	0.021
4	6	13	11	4	21	46	10	5	12	0.042
9	17	22	2	7	38	23	15	24	35	0.063
26	10	33	45	22	47	24	20	21	24	0.125
13	27	28	19	15	43	21	27	43	46	0.250
-2	8	11	6	1	-5	7	0	-6	-8	1.000
1	7	10	0	8	11	20	4	4	17	2.000
4	7	7	8	2	3	10	2	-3	2	6.000
-1	11	-1	-4	-2	-4	21	3	-7	-3	9.000
2	10	-3	-4	3	0	7	9	-2	3	13.000
-1	15	-3	8	1	8	-3	3	16	8	16.000
-4	4	2	10	4	3	-3	4	5	-1	20.000
-1	9	8	18	-1	-6	-1	-7	6	7	23.000
7	10	0	-3	-3	-1	3	-1	-8	8	27.000
10	20	2	-2	2	17	10	3	4	5	30.000
3	11	3	6	0	3	2	0	2	4	PTS (dB)
26	41	33	45	51	47	46	27	43	46	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J13

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
-6	8	27	20	21	14	14	10	12	13	0.000
-6	1	13	9	6	9	5	5	23	18	0.021
0	10	10	8	7	8	5	2	4	19	0.042
2	3	12	3	2	13	13	-2	9	16	0.063
3	-2	26	0	-4	3	4	-2	10	7	0.125
0	6	6	9	5	11	4	0	0	8	0.250
-7	-2	8	5	-2	0	8	2	0	8	1.000
-6	-5	8	4	-1	3	5	-5	5	5	2.000
-5	0	1	5	7	-1	4	-7	3	6	6.000
-6	4	1	-1	-4	2	7	-5	-4	9	9.000
-5	0	8	-7	7	0	3	-3	4	-4	13.000
-2	-1	-2	-1	8	8	5	-4	5	-5	16.000
-3	0	3	-2	0	1	6	-8	4	-5	20.000
-2	-1	7	-7	6	-2	-1	-3	7	-1	23.000
-3	-4	2	0	8	3	-3	-1	2	-3	27.000
0	2	1	1	2	-2	-1	-8	5	3	30.000
-2	-1	3	-2	4	0	0	-5	5	-2	PTS (dB)
3	10	27	20	21	14	14	10	23	19	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J15

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
6	18	6	10	9	16	15	-9	-6	4	0.000
6	9	-8	14	1	14	6	3	5	5	0.021
8	14	13	15	2	15	15	24	12	14	0.042
8	16	27	13	9	2	19	10	9	16	0.063
-1	8	-5	7	6	7	14	7	6	22	0.125
5	7	5	19	-2	5	24	10	13	8	0.250
5	6	8	13	10	18	-1	-6	-2	14	1.000
-3	-3	11	9	10	-6	2	2	12	4	2.000
6	3	7	2	2	-3	5	-3	9	2	6.000
2	1	-2	0	-3	-4	7	-1	10	-11	9.000
-3	-1	-3	3	-1	2	0	4	0	5	13.000
-2	4	-1	1	5	3	-2	-1	4	7	16.000
1	-3	-3	4	5	3	9	4	2	7	20.000
6	5	-4	-6	-9	3	19	-7	1	11	23.000
2	0	-1	-1	1	1	1	-4	8	14	27.000
-2	-4	4	6	-7	-2	7	-5	4	0	30.000
2	-1	-1	1	-2	2	9	-3	3	8	PTS (dB)
8	18	27	19	10	18	24	24	13	22	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J21

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
14	-2	35	13	21	4	15	19	18	13	0.000
2	5	9	9	18	6	15	12	2	12	0.021
5	3	15	8	6	3	14	-4	-1	8	0.042
-5	6	16	8	3	2	1	4	2	7	0.063
-4	2	3	3	2	9	8	-1	-1	9	0.125
-3	1	-2	6	4	-3	8	2	1	-4	0.250
-5	1	0	4	2	2	6	-7	0	-3	1.000
4	5	1	6	6	4	5	2	-1	-2	2.000
-4	1	6	1	4	-1	5	-6	0	4	6.000
3	2	-3	8	-2	-2	7	-7	2	-3	9.000
0	2	-3	2	-3	-2	7	-1	0	-2	13.000
-2	-2	6	5	-1	2	8	-4	2	-4	16.000
3	-3	4	1	10	-7	4	-2	-3	2	20.000
-3	0	1	1	6	-1	7	0	-6	-4	23.000
-7	2	6	8	-1	0	6	-5	-5	-1	27.000
-7	-3	4	4	2	1	10	-7	-6	2	30.000
-3	-1	4	3	4	-2	7	-3	-5	0	PTS (dB)
14	6	35	13	21	9	15	19	18	13	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J14 A

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
0	60	44	32	29	21	21	31	42	34	0.000
0	56	60	16	21	29	39	43	18	38	0.021
10	50	34	32	19	21	10	21	11	34	0.042
30	60	34	22	19	51	37	38	34	64	0.063
13	42	46	15	20	17	35	60	26	18	0.125
-6	0	8	22	26	22	24	20	10	66	0.250
-3	1	43	15	29	3	15	11	20	8	1.000
-7	31	29	25	26	2	25	11	49	51	2.000
-7	0	-7	-3	-1	2	11	22	10	5	6.000
0	0	-16	12	9	-9	0	11	1	4	9.000
-4	3	-4	1	0	1	-12	-1	7	4	13.000
-11	5	-10	4	2	-6	1	-5	6	6	16.000
-1	-5	-12	-8	3	-3	0	2	8	7	20.000
3	2	6	5	0	-3	-5	-10	-4	-2	23.000
0	2	-7	-3	7	-6	0	-2	-2	3	27.000
-8	0	6	-5	10	-7	4	-7	-7	6	30.000
-2	0	-1	-3	5	-5	0	-4	-1	3	PTS (dB)
30	60	60	32	29	51	39	60	49	66	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA J20A

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
-10	2	24	0	7	20	38	25	-2	9	0.000
1	22	6	10	-11	23	18	41	25	40	0.021
19	28	13	23	11	14	39	42	43	14	0.042
17	0	1	35	17	44	49	43	10	30	0.063
6	20	10	12	12	35	21	12	35	18	0.125
20	28	28	19	27	36	17	29	21	19	0.250
9	-7	8	-3	6	-1	7	15	0	2	1.000
4	0	11	9	17	-3	10	23	1	21	2.000
1	-3	5	8	9	-2	5	12	-1	6	6.000
0	-11	6	11	4	0	1	5	1	9	9.000
-3	-3	5	-2	0	-10	-2	7	2	-8	13.000
8	0	2	3	0	6	5	11	-4	-5	16.000
-8	4	3	-2	-3	-3	4	2	0	9	20.000
-3	0	-7	-1	2	-2	2	4	0	-1	23.000
-6	4	2	-2	1	3	13	9	4	7	27.000
-3	-3	-5	1	2	-2	-2	12	-1	9	30.000
-5	2	-1	-1	1	-1	5	7	1	6	PTS (dB)
20	28	28	35	27	44	49	43	43	40	MAXIMUM TS (dB)

Group F - Postexposure threshold shifts

Animals: X4R*
J9R
X3R
J1R
J4R
G29R

*R refers to the right ear

Group F

POSTEXPOSURE THRESHOLD SHIFT (dB)

EXPOSURE: 147 dB 10 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
38	47	47	46	64	55	55	42	48	31	0.000
42	49	52	46	51	54	50	51	49	39	0.021
52	53	55	54	63	62	51	53	58	45	0.042
40	48	52	55	56	63	57	56	55	53	0.063
41	50	57	53	63	62	53	53	52	45	0.125
37	48	63	53	53	54	59	48	44	48	0.250
28	42	49	46	45	45	47	32	36	31	1.000
17	38	37	37	37	32	39	27	32	29	2.000
22	31	26	33	27	31	27	18	25	26	6.000
18	24	24	24	29	31	21	24	27	21	9.000
12	16	22	25	22	24	24	17	16	16	13.000
10	19	20	24	21	24	30	18	19	19	16.000
6	17	16	24	22	21	22	16	19	15	20.000
7	15	19	14	22	19	21	19	13	18	23.000
6	15	21	18	24	21	19	18	16	14	27.000
8	14	19	17	22	23	19	20	12	17	30.000
7	15	19	18	23	21	20	18	15	16	MEAN GROUP PTS (dB)
7.4	9.2	13.7	16.8	19.0	18.2	20.3	15.2	15.5	14.7	SD GROUP PTS (dB)
54	60	68	64	72	69	69	65	67	57	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
16.4	15.4	20.6	16.3	17.5	13.6	9.6	12.6	13.5	16.1	0.000
11.5	22.0	18.9	13.8	13.7	15.4	15.2	16.5	10.3	13.0	0.021
22.0	18.6	20.0	19.5	16.8	13.6	20.7	9.5	22.6	9.9	0.042
16.4	21.7	22.6	25.7	23.9	17.6	14.4	8.1	21.3	14.4	0.063
21.5	25.0	30.6	24.6	20.7	17.6	22.0	12.1	16.3	18.5	0.125
16.2	17.4	18.0	26.2	22.6	16.0	21.9	10.7	25.7	26.4	0.250
21.1	24.0	27.9	28.6	31.8	18.7	27.7	17.5	22.9	23.8	1.000
15.9	19.3	27.0	31.1	28.0	26.2	25.3	16.1	20.7	19.9	2.000
16.8	12.4	15.0	22.0	20.1	22.2	20.2	12.1	14.4	26.3	6.000
12.5	18.7	22.1	26.1	23.1	20.0	24.5	13.3	18.9	20.0	9.000
8.6	15.7	18.8	17.8	20.6	15.5	20.7	16.4	16.8	17.8	13.000
11.2	10.6	17.0	16.6	25.3	14.1	18.5	13.1	17.1	19.7	16.000
10.6	13.8	11.7	18.6	18.9	20.2	16.8	11.3	17.0	13.4	20.000
7.2	7.2	11.8	19.4	19.6	15.1	23.0	17.1	16.6	19.5	23.000
9.5	8.3	18.7	16.6	16.7	21.7	23.0	18.7	11.9	13.8	27.000
6.5	9.1	16.4	14.0	22.2	19.2	19.6	16.3	18.6	13.5	30.000

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA X4

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
61	47	52	59	81	58	67	56	51	24	0.000
33	68	52	59	61	51	59	82	49	54	0.021
72	63	52	74	74	54	35	53	59	47	0.042
35	41	69	72	76	64	39	63	58	61	0.063
56	54	71	59	81	71	52	45	65	32	0.125
46	56	72	71	53	51	81	58	66	74	0.250
33	61	79	67	80	57	62	33	53	50	1.000
15	56	58	58	56	40	60	50	46	53	2.000
42	41	25	52	23	51	37	19	33	71	6.000
28	29	33	46	51	39	51	43	46	52	9.000
9	17	37	44	40	23	48	36	33	41	13.000
13	20	35	29	41	20	49	25	33	41	16.000
12	22	10	31	39	29	37	29	39	35	20.000
7	20	35	22	44	23	50	41	33	43	23.000
2	23	33	35	37	42	51	47	27	31	27.000
9	16	34	26	50	49	47	45	39	33	30.000
7	20	28	29	42	36	46	41	34	36	PTS (dB)
72	68	79	74	81	71	81	82	66	74	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA J9

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
17	44	27	46	60	44	60	23	63	8	0.000
35	30	51	52	58	56	34	41	39	21	0.021
31	40	30	47	71	64	60	51	58	32	0.042
33	49	40	43	56	62	58	51	18	29	0.063
27	44	17	46	60	54	43	43	39	26	0.125
16	27	51	43	49	46	33	40	5	1	0.250
-2	18	12	7	18	36	8	14	10	3	1.000
6	19	0	3	7	-5	10	17	1	21	2.000
1	18	10	2	4	-3	1	7	3	8	6.000
0	2	-2	-1	18	27	-14	8	7	9	9.000
6	-2	0	11	8	15	9	9	-3	0	13.000
2	9	0	11	-6	30	17	6	2	6	16.000
-4	8	9	11	17	-7	-1	6	11	9	20.000
-3	8	8	-9	17	6	-3	-2	-7	-1	23.000
-3	6	-3	8	20	-7	-2	5	7	6	27.000
4	4	1	4	3	1	-2	1	-1	5	30.000
-2	6	4	4	14	-2	-2	2	2	5	PTS (dB)
35	49	51	52	71	64	60	51	63	32	MAXIMUM TS (dB)

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IMPULSES ON HEARING AND..(U) TEXAS UNIV AT DALLAS
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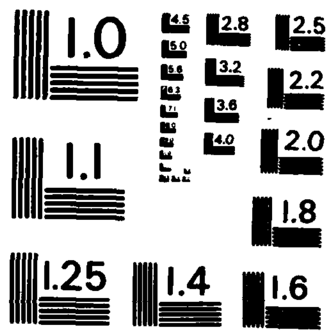


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA X3

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
47	53	83	65	80	72	64	41	48	49	0.000
61	73	72	58	64	60	67	42	59	53	0.021
71	67	79	72	82	67	76	67	71	44	0.042
49	60	70	69	76	61	67	53	57	64	0.063
52	65	82	76	88	78	75	55	62	63	0.125
41	56	74	81	85	68	75	50	65	67	0.250
50	70	72	84	80	69	88	57	69	67	1.000
39	54	62	77	76	65	68	42	49	54	2.000
40	43	43	62	61	60	55	40	47	45	6.000
[illegible]	47	57	62	65	65	46	35	54	40	9.000
[illegible]	27	41	50	55	53	52	39	41	35	13.000
21	23	44	52	61	49	58	40	47	47	16.000
22	39	35	53	50	53	46	30	41	27	20.000
19	20	28	45	49	46	47	38	33	41	23.000
20	22	46	40	51	50	46	34	36	31	27.000
13	25	32	37	48	45	39	29	34	34	30.000
18	27	35	43	50	49	45	33	36	34	PTS (dB)
71	73	83	84	88	78	88	67	71	67	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA J1

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
43	55	47	44	57	53	50	37	23	19	0.000
53	48	55	48	55	63	60	37	50	32	0.021
74	69	69	67	64	72	60	59	68	61	0.042
69	70	72	88	73	76	74	66	74	68	0.063
71	84	88	81	69	78	76	76	73	72	0.125
62	63	73	74	70	79	74	55	64	60	0.250
50	51	63	49	54	57	55	47	45	32	1.000
35	45	48	48	46	46	48	28	51	17	2.000
26	35	45	35	32	29	27	16	23	6	6.000
22	35	36	29	18	25	16	15	19	8	9.000
29	38	36	19	17	26	18	4	10	6	13.000
26	33	21	27	18	19	15	10	16	8	16.000
13	23	26	28	20	27	16	15	17	8	20.000
8	24	26	18	17	19	8	12	10	13	23.000
15	22	31	17	17	19	6	2	8	6	27.000
14	22	34	22	22	11	9	5	-1	15	30.000
12	23	29	21	19	19	10	9	8	10	PTS (dB)
74	84	88	88	73	79	76	76	74	72	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA J4

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
38	64	44	42	35	66	46	56	55	43	0.000
35	57	64	34	34	69	49	48	61	41	0.021
34	55	67	28	53	75	58	40	80	49	0.042
23	59	48	39	42	84	65	45	76	48	0.063
15	45	64	40	51	61	55	50	38	41	0.125
30	61	75	30	37	42	60	30	40	40	0.250
31	44	51	50	34	30	37	15	23	17	1.000
8	46	47	40	33	39	39	10	35	22	2.000
12	37	17	27	32	28	37	16	26	17	6.000
16	28	17	10	8	28	25	17	24	14	9.000
13	17	16	16	13	14	17	8	7	8	13.000
-1	7	16	21	7	10	18	8	7	8	16.000
-4	11	13	24	3	12	20	10	9	1	20.000
8	14	11	11	7	13	22	12	13	8	23.000
6	11	12	10	8	14	13	13	12	0	27.000
-2	14	14	12	5	16	16	16	5	3	30.000
2	12	12	14	5	14	18	13	10	3	PTS (dB)
38	64	75	50	53	84	65	56	80	49	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFTS (dB)

CHINCHILLA G29

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
22	19	28	18	71	35	45	41	49	40	0.000
39	17	17	25	33	25	29	54	35	34	0.021
32	22	34	38	35	38	19	47	15	38	0.042
32	9	15	19	16	32	41	60	46	48	0.063
27	10	22	15	31	32	17	51	35	34	0.125
27	25	31	18	22	39	31	53	22	43	0.250
10	10	20	20	4	21	30	26	17	18	1.000
1	10	6	-2	5	6	7	15	13	7	2.000
11	14	15	18	11	22	7	8	21	11	6.000
11	1	5	-1	15	4	5	23	11	4	9.000
6	0	1	8	2	11	2	4	10	4	13.000
2	17	6	4	5	15	25	19	11	4	16.000
1	1	5	-2	4	14	14	5	-2	7	20.000
4	7	9	-4	1	5	1	12	-1	3	23.000
-3	7	7	-3	11	5	3	4	9	8	27.000
14	4	0	0	3	17	5	21	-1	13	30.000
4	5	5	-2	5	11	6	11	2	7	PTS (dB)
39	25	34	38	71	39	45	60	49	48	MAXIMUM TS (dB)

Group G - Postexposure threshold shifts

Animals: E115R*
F1R
E138R
G2R
G20R
G5R

*R refers to the right ear

Group G

POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: 147 dB 100 IMPULSES

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
58	78	77	76	80	81		69	63	54	0.000
57	59	72	70	72	70		60	68	53	0.021
45	60	69	74	76	75		69	66	53	0.042
52	67	80	82	83	75		70	65	55	0.063
59	67	82	83	84	81		67	72	55	0.125
58	64	76	81	77	82		69	67	53	0.250
51	63	79	80	76	71		60	68	55	1.000
48	55	71	66	67	66		51	56	50	2.000
39	51	61	55	56	58		48	47	41	6.000
30	48	52	56	55	52		44	42	38	9.000
30	44	44	50	49	51		37	42	34	13.000
25	41	43	49	49	45		41	42	38	16.000
26	36	44	47	50	41		42	38	35	20.000
25	41	46	41	47	43		41	38	38	23.000
24	35	33	42	46	49		37	32	39	27.000
21	34	33	49	43	40		37	40	36	30.000
24	37	39	45	46	43		39	37	37	MEAN GROUP PTS (dB)
8.4	7.0	6.2	2.6	6.6	4.4	0.0	3.0	4.9	5.6	SD GROUP PTS (dB)
71	80	89	87	89	88		75	79	64	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
14.3	12.9	6.0	8.7	11.6	18.7		5.4	14.2	11.3	0.000
14.2	10.6	10.0	6.8	9.0	9.0		11.8	6.9	10.6	0.021
7.8	6.9	6.3	9.3	7.2	9.4		10.7	7.8	7.3	0.042
16.7	16.6	21.7	9.8	13.0	13.7		10.6	14.8	11.8	0.063
20.9	17.4	19.9	11.3	12.9	11.7		8.2	7.6	6.7	0.125
11.4	18.5	19.7	15.8	16.5	12.4		13.4	11.6	11.5	0.250
18.6	15.2	11.7	8.0	5.6	4.5		13.6	13.8	9.2	1.000
14.3	19.9	10.8	14.5	14.6	13.9		9.2	14.7	10.4	2.000
14.1	12.4	8.8	10.0	12.9	10.3		7.1	8.1	15.4	6.000
10.3	6.4	11.0	7.5	10.4	8.1		10.2	15.3	19.2	9.000
9.3	11.3	8.1	10.8	6.9	10.9		4.5	7.0	11.9	13.000
9.3	13.9	7.5	8.4	3.4	6.6		4.3	11.1	7.4	16.000
8.8	7.2	11.0	5.1	11.3	8.1		11.5	3.9	4.4	20.000
10.8	10.4	7.1	5.3	14.4	5.7		2.8	5.6	9.4	23.000
7.6	7.2	11.3	10.9	14.2	5.3		3.9	9.9	7.9	27.000
11.4	9.9	8.0	2.8	8.9	8.2		6.6	8.4	8.8	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E115

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
45	60	77	77	71	77		69	40	38	0.000
39	44	80	75	61	80		40	64	64	0.021
36	54	74	57	68	76		55	64	44	0.042
31	63	42	67	68	72		59	48	60	0.063
42	54	46	70	69	65		61	69	51	0.125
37	38	41	51	55	65		66	61	55	0.250
35	56	78	80	84	71		34	53	54	1.000
53	27	61	41	52	54		36	28	64	2.000
28	46	52	48	72	68		53	45	43	6.000
15	41	56	66	65	43		57	58	46	9.000
13	58	45	65	57	56		[illegible]	49	33	13.000
10	38	45	52	47	51		46	51	47	16.000
21	35	35	51	63	42		61	38	36	20.000
13	47	47	35	21	46		46	36	31	23.000
23	25	42	40	48	42		35	14	46	27.000
11	[illegible]	35	51	29	37		29	26	48	30.000
17	34	39	44	41	42		43	29	40	PTS (dB)
53	63	80	80	84	80		69	69	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F1

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
68	70	70	59	61	58		68	56	54	0.000
53	60	71	59	71	58		58	66	54	0.021
38	50	71	69	68	68		68	56	54	0.042
38	50	80	78	80	58		58	56	54	0.063
28	60	80	68	80	68		58	66	54	0.125
59	61	71	79	71	69		59	57	45	0.250
39	51	61	69	71	69		59	57	45	1.000
38	50	60	58	50	48		48	56	34	2.000
28	50	50	48	50	48		48	36	24	6.000
44	46	56	54	46	54		44	42	20	9.000
24	36	46	44	46	44		44	32	30	13.000
13	25	35	53	45	43		43	31	29	16.000
12	24	34	42	44	42		42	40	28	20.000
11	23	33	51	53	41		41	29	27	23.000
10	30	32	50	42	50		40	38	26	27.000
9	21	31	49	41	29		39	37	25	30.000
11	25	33	48	45	41		41	36	27	PTS (dB)
68	70	80	79	80	69		68	66	54	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E138

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
68	74	74	77	82	64		60	70	46	0.000
51	67	53	71	81	63		58	59	45	0.021
56	69	62	80	80	62		67	68	45	0.042
71	63	93	81	81	73		68	59	35	0.063
84	68	95	88	88	80		68	62	52	0.125
58	74	94	82	82	84		59	70	36	0.250
84	84	94	82	82	74		70	91	69	1.000
66	74	84	82	82	64		60	60	46	2.000
48	44	64	72	62	54		40	50	26	6.000
38	[illegible]	34	52	42	44		30	20	16	9.000
38	54	54	52	52	44		30	40	46	13.000
33	44	54	52	52	54		40	60	46	16.000
38	54	64	52	62	44		30	30	36	20.000
28	54	54	42	52	34		40	40	46	23.000
[illegible]	44	34	32	22	44		40	30	46	27.000
38	44	44	52	42	44		30	40	36	30.000
33	44	49	44	44	41		35	35	41	PTS (dB)
84	84	95	88	88	84		70	91	69	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G2

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
59	86	73	81	88	108		69	81	64	0.000
64	74	78	76	68	80		74	80	64	0.021
53	63	77	75	87	89		88	79	63	0.042
52	82	76	84	86	88		82	78	62	0.063
71	81	95	93	85	87		81	77	51	0.125
70	90	94	92	64	86		80	76	60	0.250
39	59	73	91	73	65		59	65	49	1.000
28	48	62	70	62	64		48	54	48	2.000
27	37	61	49	51	63		47	53	37	6.000
26	46	50	48	50	62		36	42	36	9.000
32	39	35	44	40	45		36	42	33	13.000
31	38	34	32	48	39		38	39	32	16.000
28	43	45	41	35	41		42	39	39	20.000
37	42	50	42	40	47		41	35	38	23.000
22	39	31	41	43	49		36	35	36	27.000
19	38	32	48	41	48		45	42	32	30.000
27	41	40	43	40	46		41	38	36	PTS (dB)
71	90	95	93	88	108		88	81	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G20

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
35	79	83	81	85	84		70	59	52	0.000
81	52	78	76	68	71		69	69	37	0.021
46	63	62	80	78	79		66	61	57	0.042
49	52	83	88	76	67		68	60	50	0.063
56	45	78	83	75	93		69	79	56	0.125
56	50	82	90	90	87		57	55	51	0.250
48	48	79	74	76	69		69	65	50	1.000
43	51	78	73	84	83		59	68	56	2.000
40	54	69	64	36	45		41	40	64	6.000
23	45	52	51	63	51		46	31	43	9.000
23	28	33	60	44	46		37	38	14	13.000
18	33	46	52	48	38		43	37	35	16.000
23	36	48	45	43	26		48	41	40	20.000
34	37	48	39	56	41		37	45	36	23.000
27	40	13	60	64	56		38	32	43	27.000
16	27	20	51	52	35		35	39	32	30.000
25	35	32	49	53	39		40	39	38	PTS (dB)
81	79	83	90	90	93		70	79	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G5

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
70	97	85	82	92	94		77	71	69	0.000
55	59	71	66	85	71		58	67	54	0.021
43	59	68	81	77	76		67	65	54	0.042
72	92	106	96	106	95		82	88	69	0.063
72	92	99	94	106	91		63	81	69	0.125
66	71	74	93	99	99		90	85	69	0.250
62	80	89	86	71	78		67	76	64	1.000
57	82	79	73	74	81		56	69	55	2.000
62	73	71	51	63	68		59	58	52	6.000
31	58	67	64	64	61		60	60	69	9.000
42	48	49	36	55	71		38	51	47	13.000
29	66	46	54	54	48		34	36	38	16.000
31	44	40	52	52	50		31	37	34	20.000
28	41	44	40	61	49		40	42	53	23.000
32	33	45	32	54	54		30	44	35	27.000
31	46	38	44	54	50		43	53	46	30.000
31	41	42	42	56	51		36	44	42	PTS (dB)
72	97	106	96	106	99		90	88	69	MAXIMUM TS (dB)

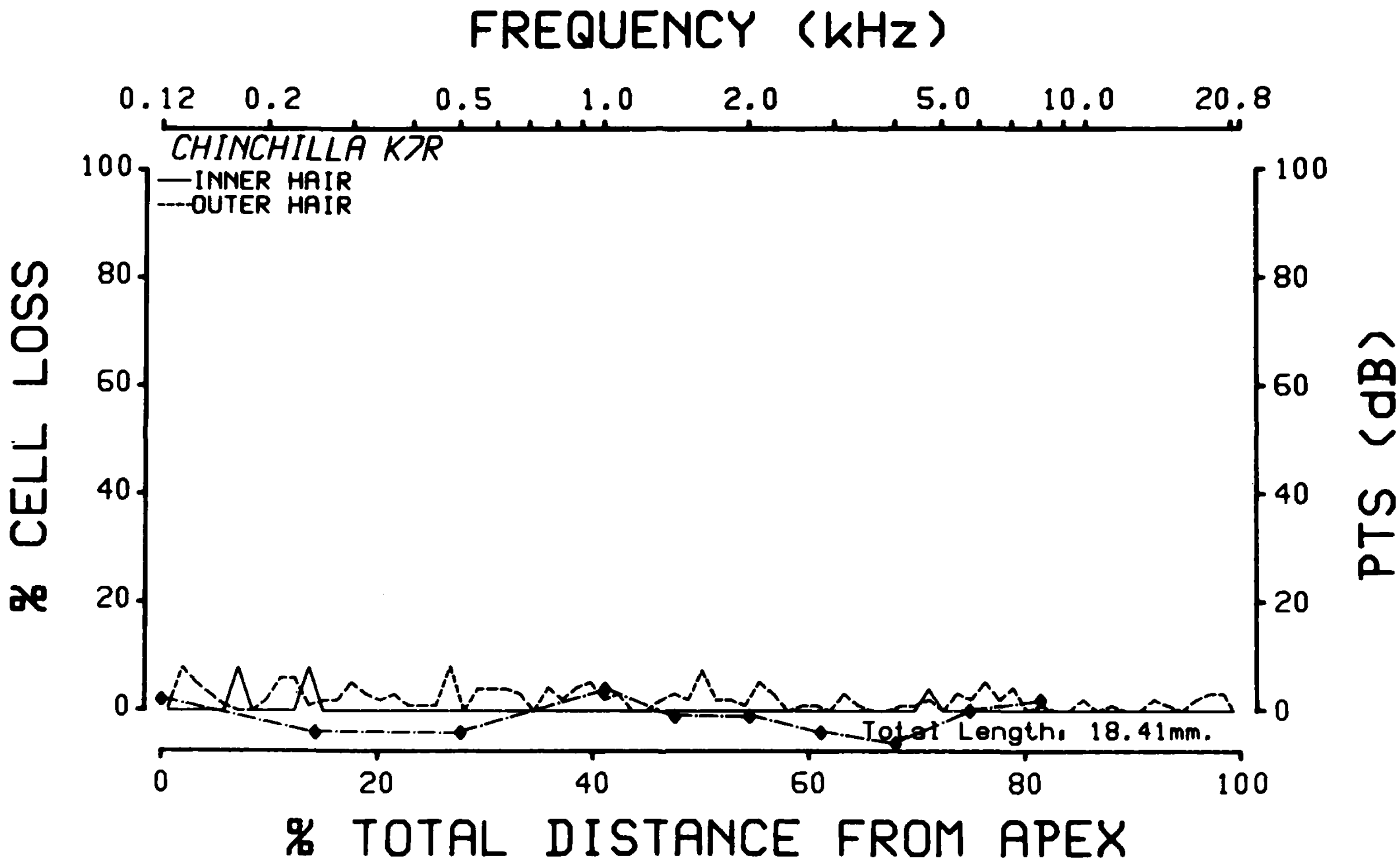
APPENDIX C

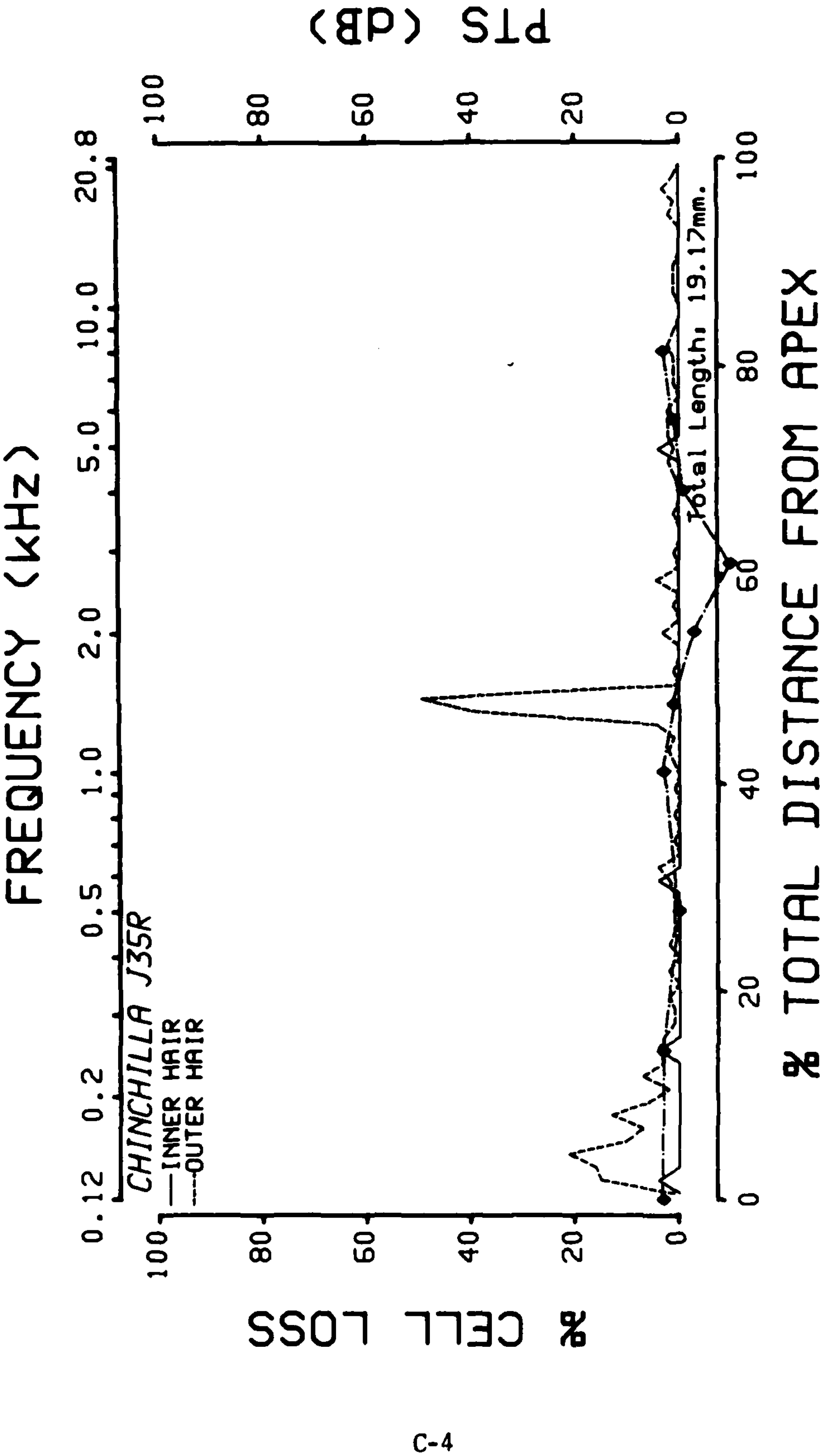
Cochleograms and permanent threshold shifts for each animal used in this study arranged by exposure group.

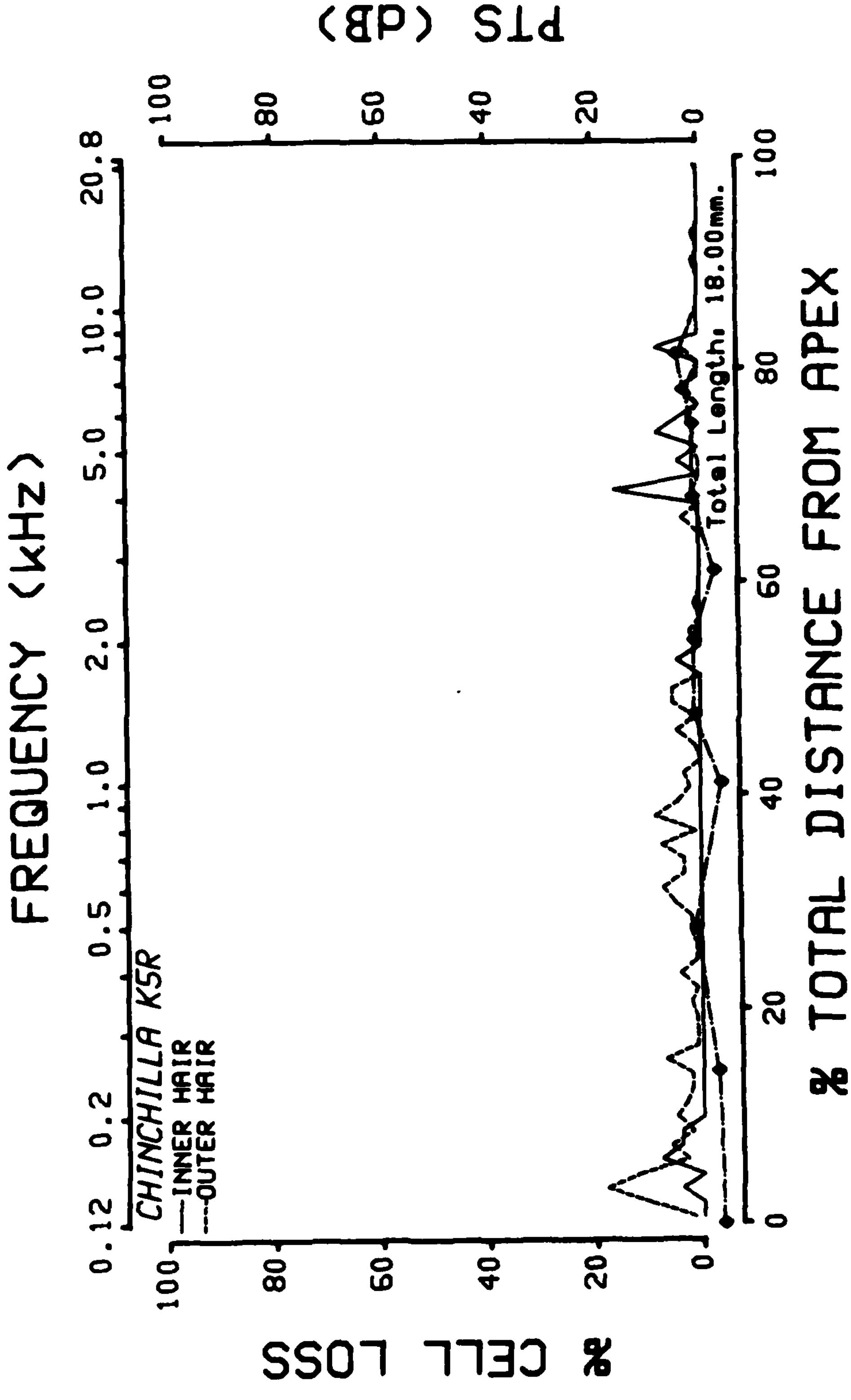
Group A - Exposure Condition: 100X @ 131 dB

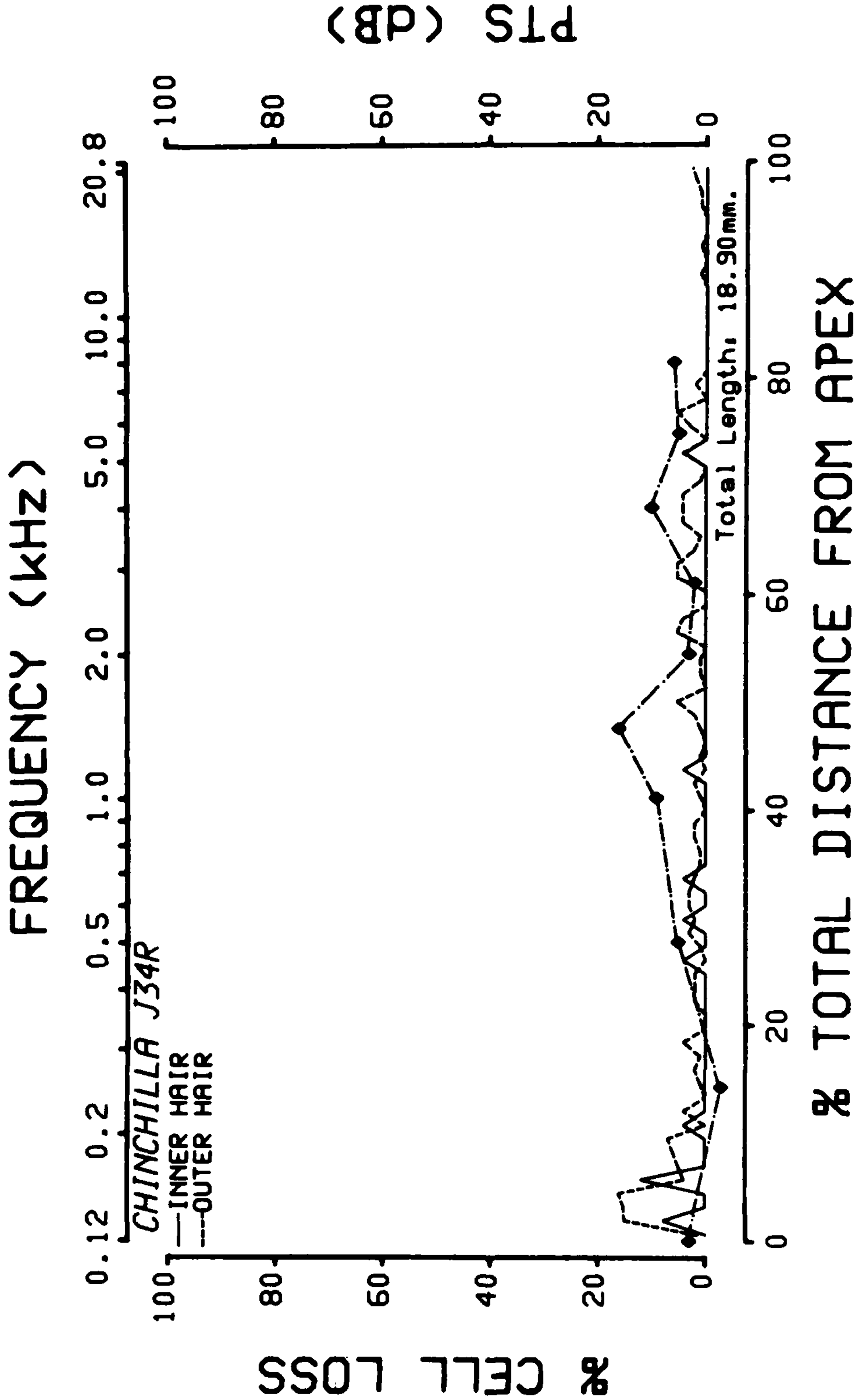
Animals: K7R*
J35R
K5R
J34R
K105R

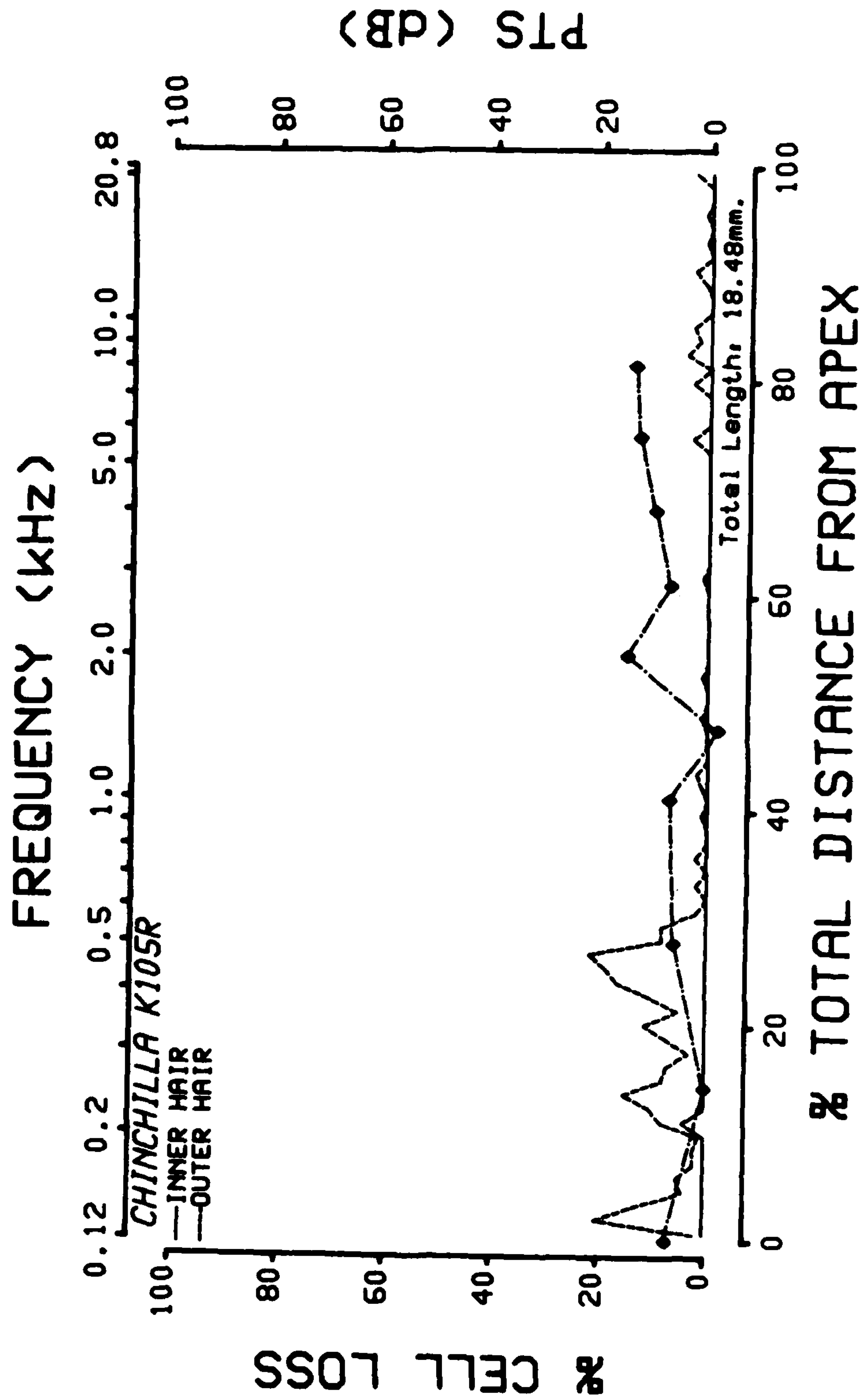
*R refers to the right ear


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K7R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
Total Length: 18.41mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
CHINCHILLA J35R
—INNER HAIR
---OUTER HAIR
Total Length: 19.17mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
Total Length: 18.00mm.
CHINCHILLA K5R
—INNER HAIR
---OUTER HAIR

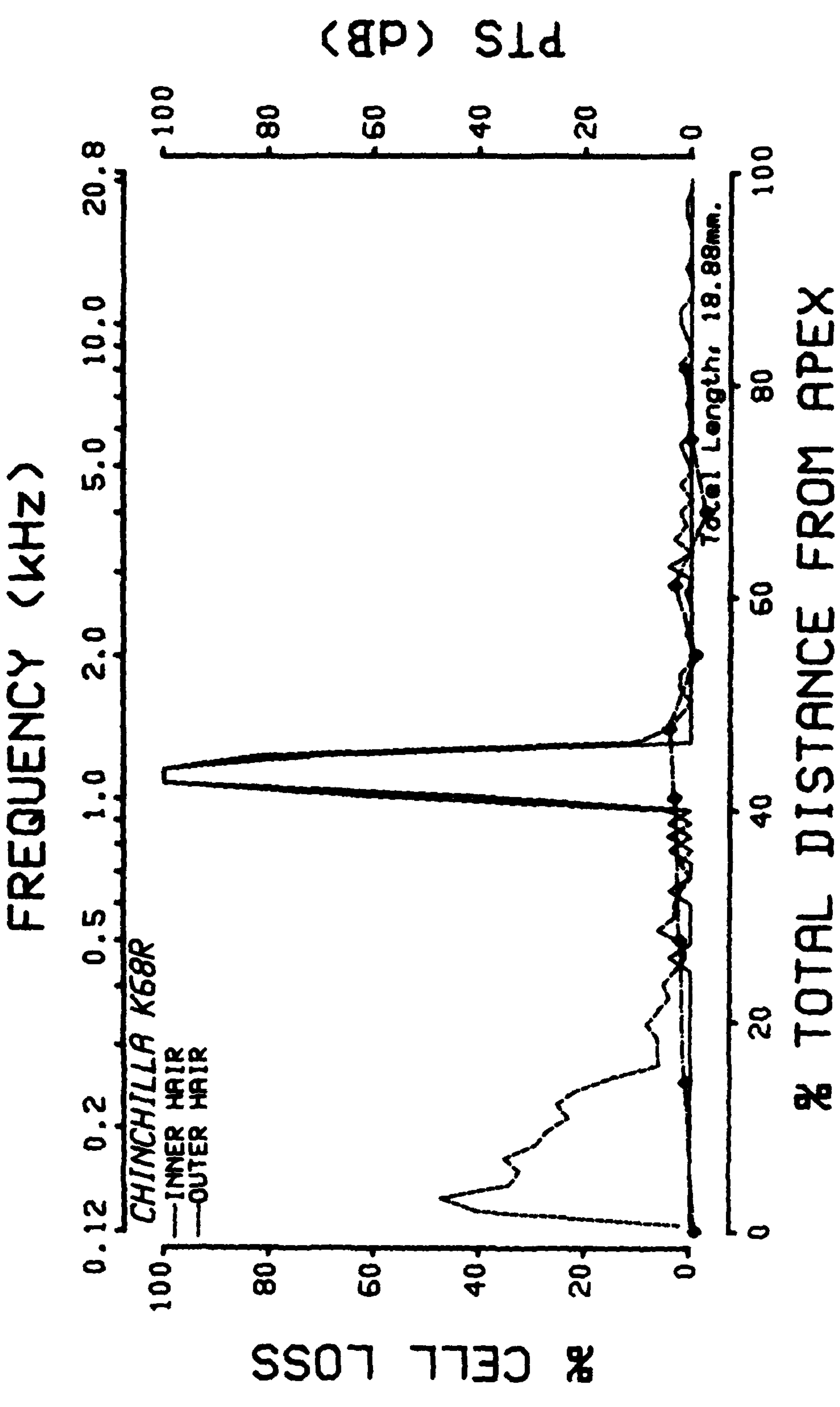

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA J34R
—INNER HAIR
---OUTER HAIR
Total Length: 18.90mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100
% CELL LOSS
PTS (dB)

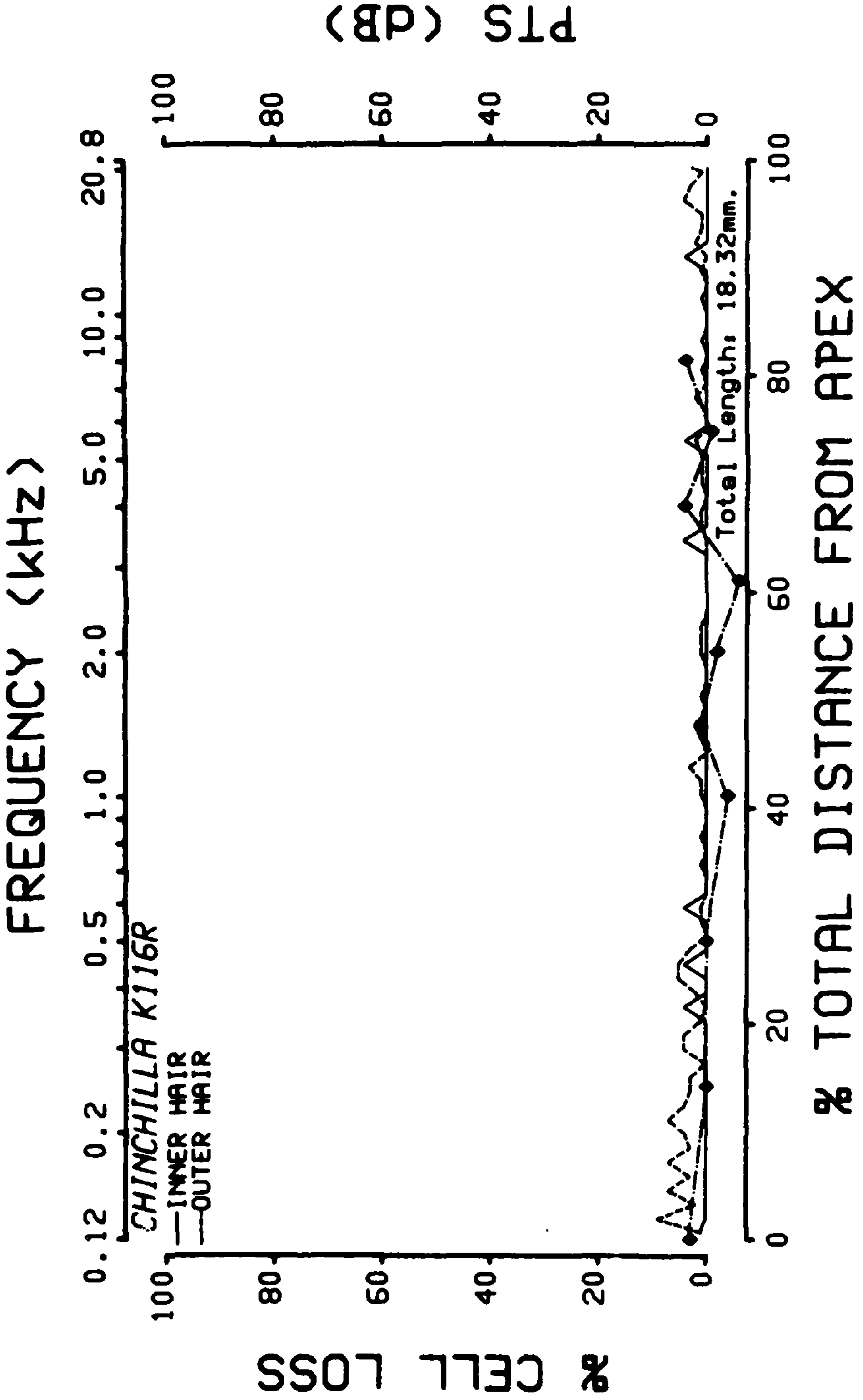

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K105R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length: 18.48mm.
% TOTAL DISTANCE FROM APEX

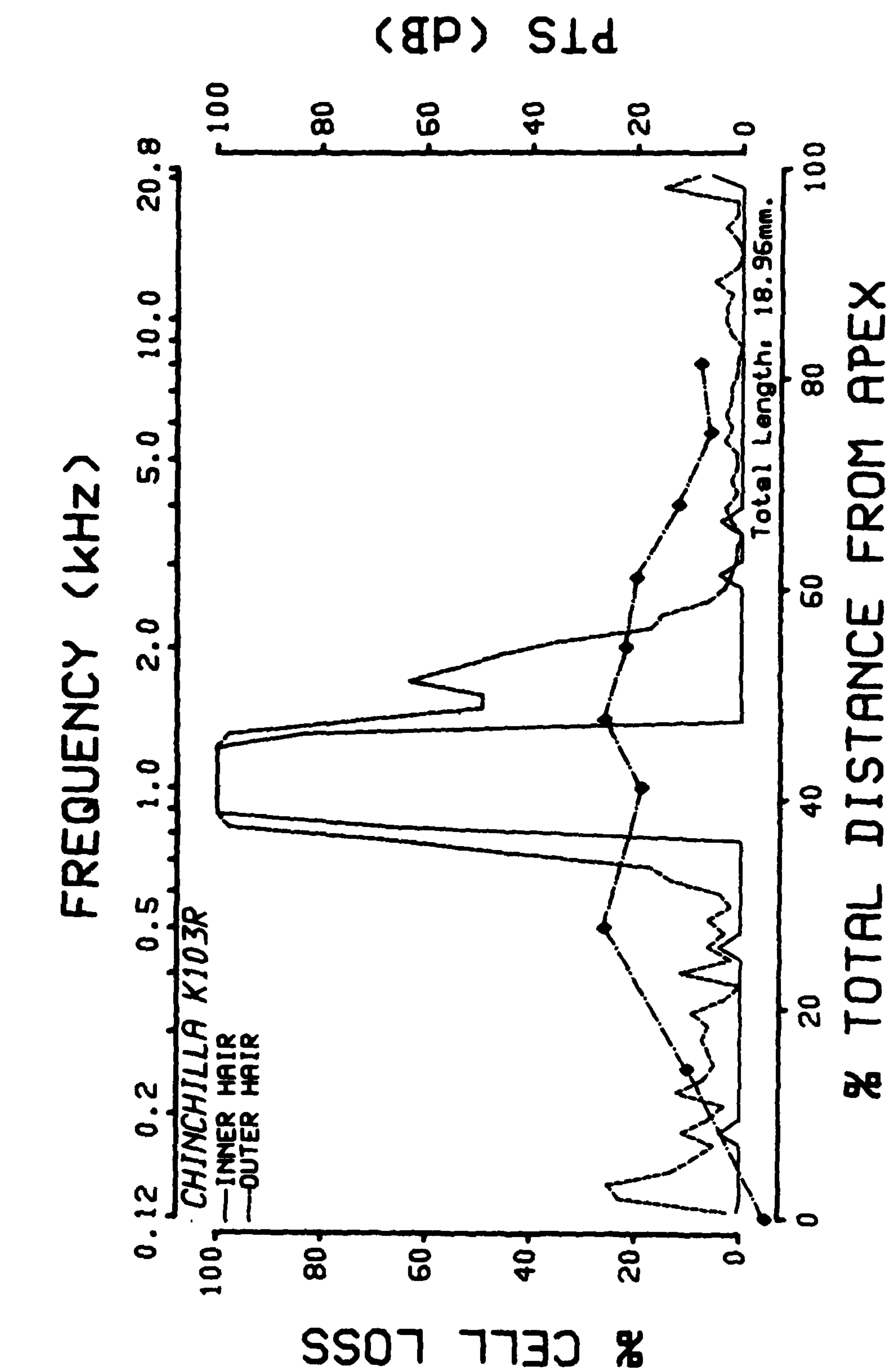
Group B - Exposure Condition: 100X @ 135 dB

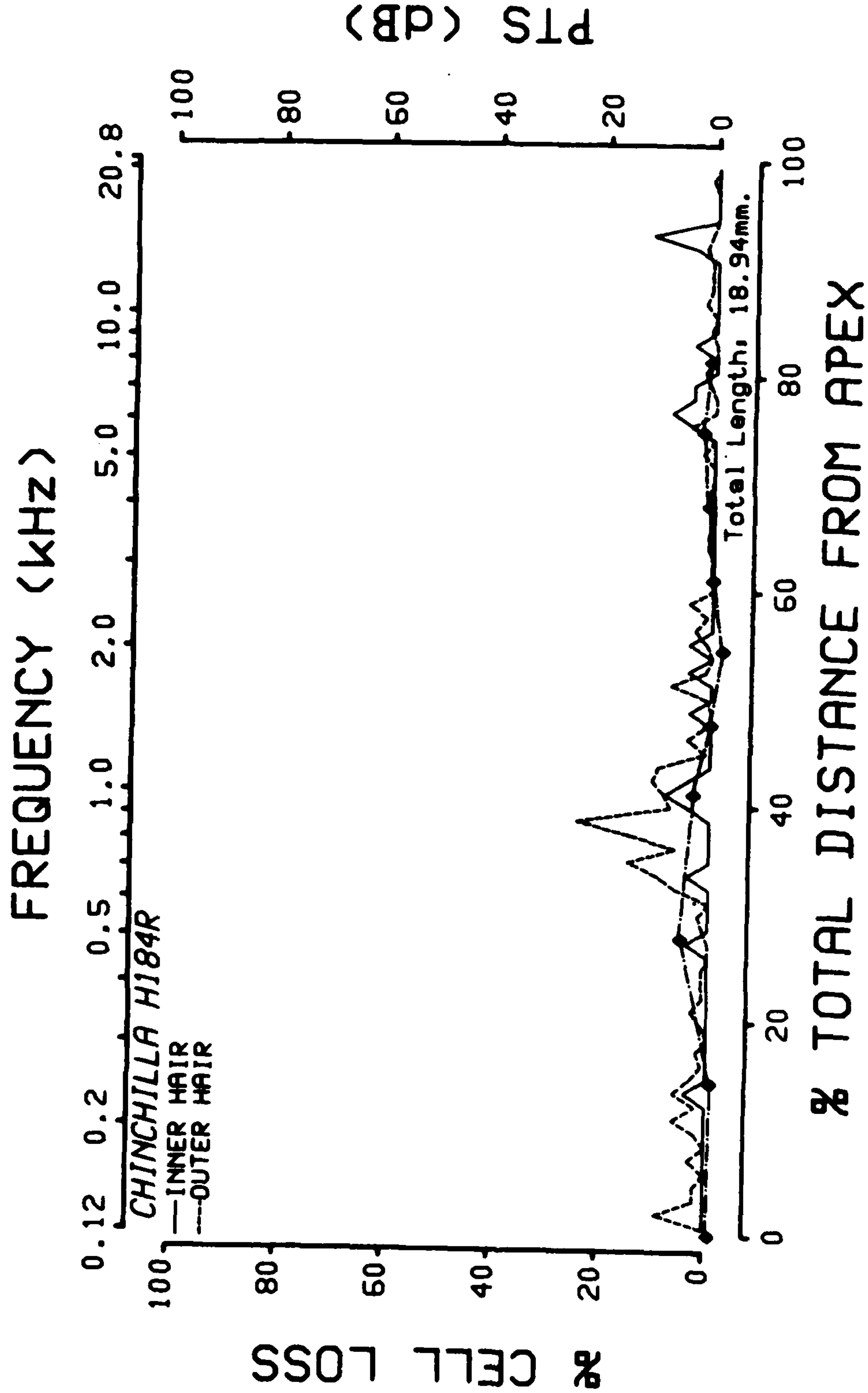
Animals: K68R*
K116R
K103R
H184R
K108R
K21R

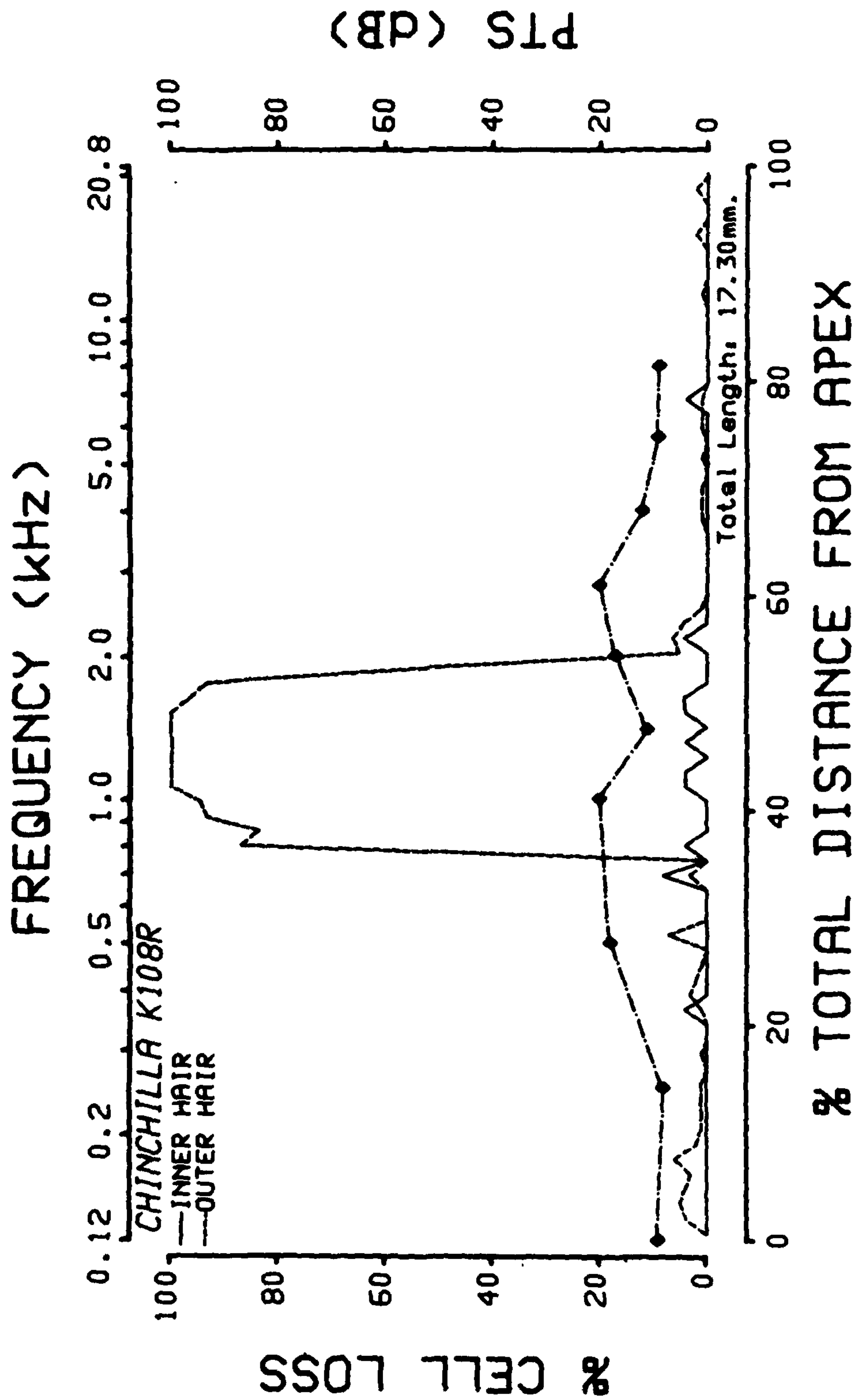
*R refers to the right ear

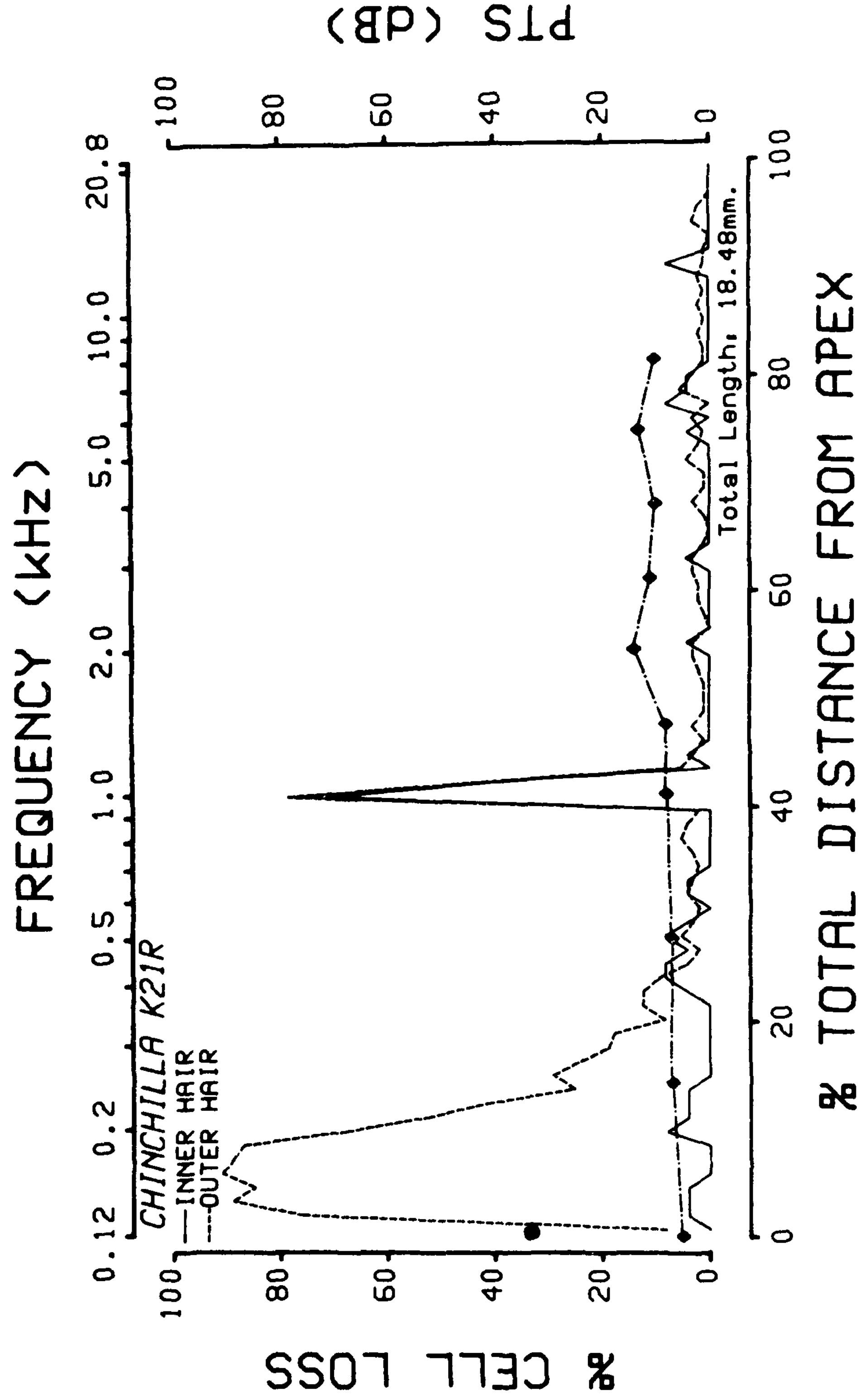

FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
PTS (dB)
100 80 60 40 20 0
% CELL LOSS
100 80 60 40 20 0
% TOTAL DISTANCE FROM APEX
0 20 40 60 80 100
CHINCHILLA K68R
—INNER HAIR
—OUTER HAIR
Total Length: 18.88mm.


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA K116R
INNER HAIR
OUTER HAIR
Total Length: 18.32mm.


FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA K103R
—INNER HAIR
—OUTER HAIR
Total Length: 18.96mm.


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA H184R
—INNER HAIR
---OUTER HAIR
Total Length: 18.94mm.


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
100
80
60
40
20
0
CHINCHILLA K108R
—INNER HAIR
—OUTER HAIR
Total Length: 17.30mm.
% TOTAL DISTANCE FROM APEX

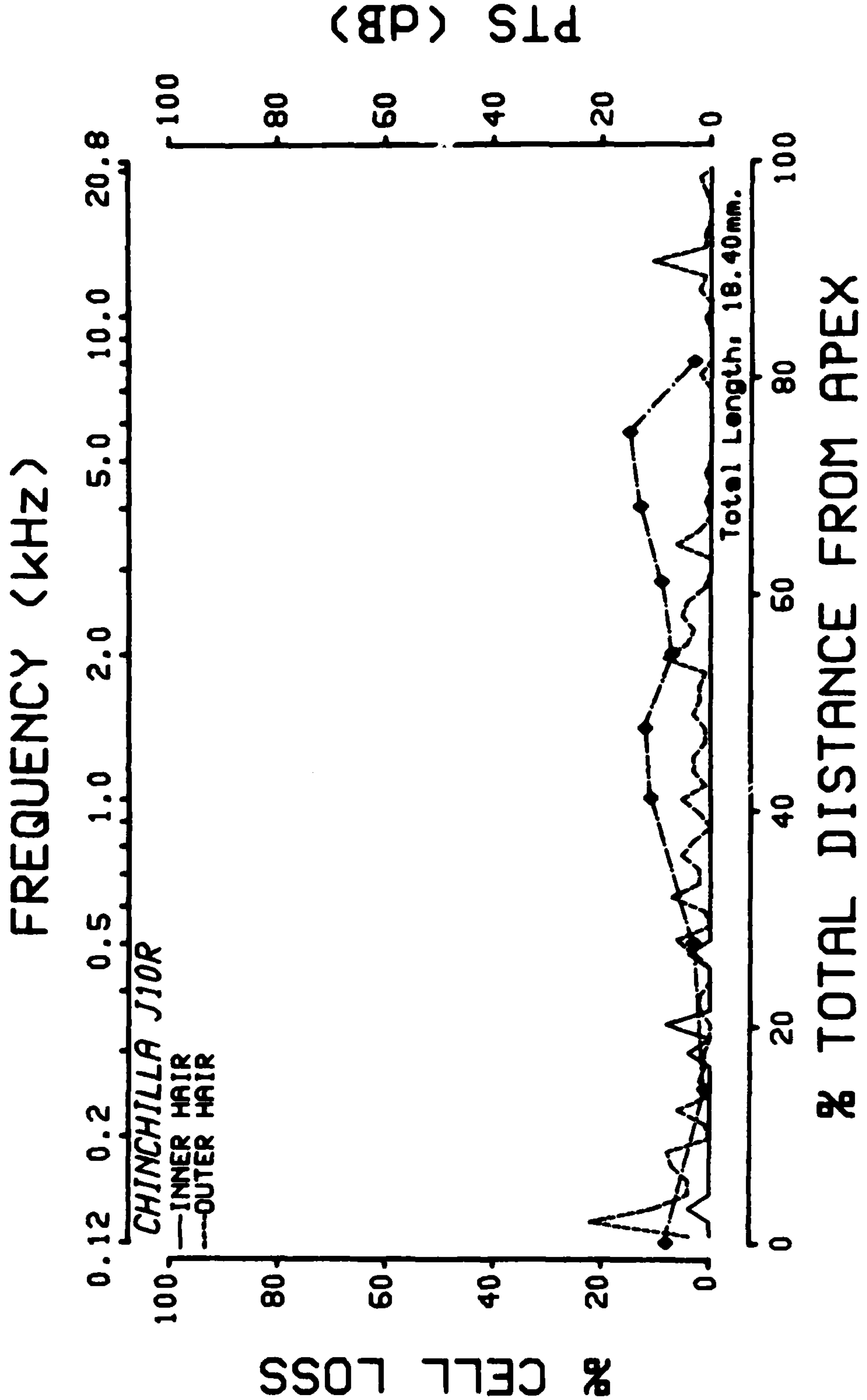


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA K21R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
Total Length: 18.48mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

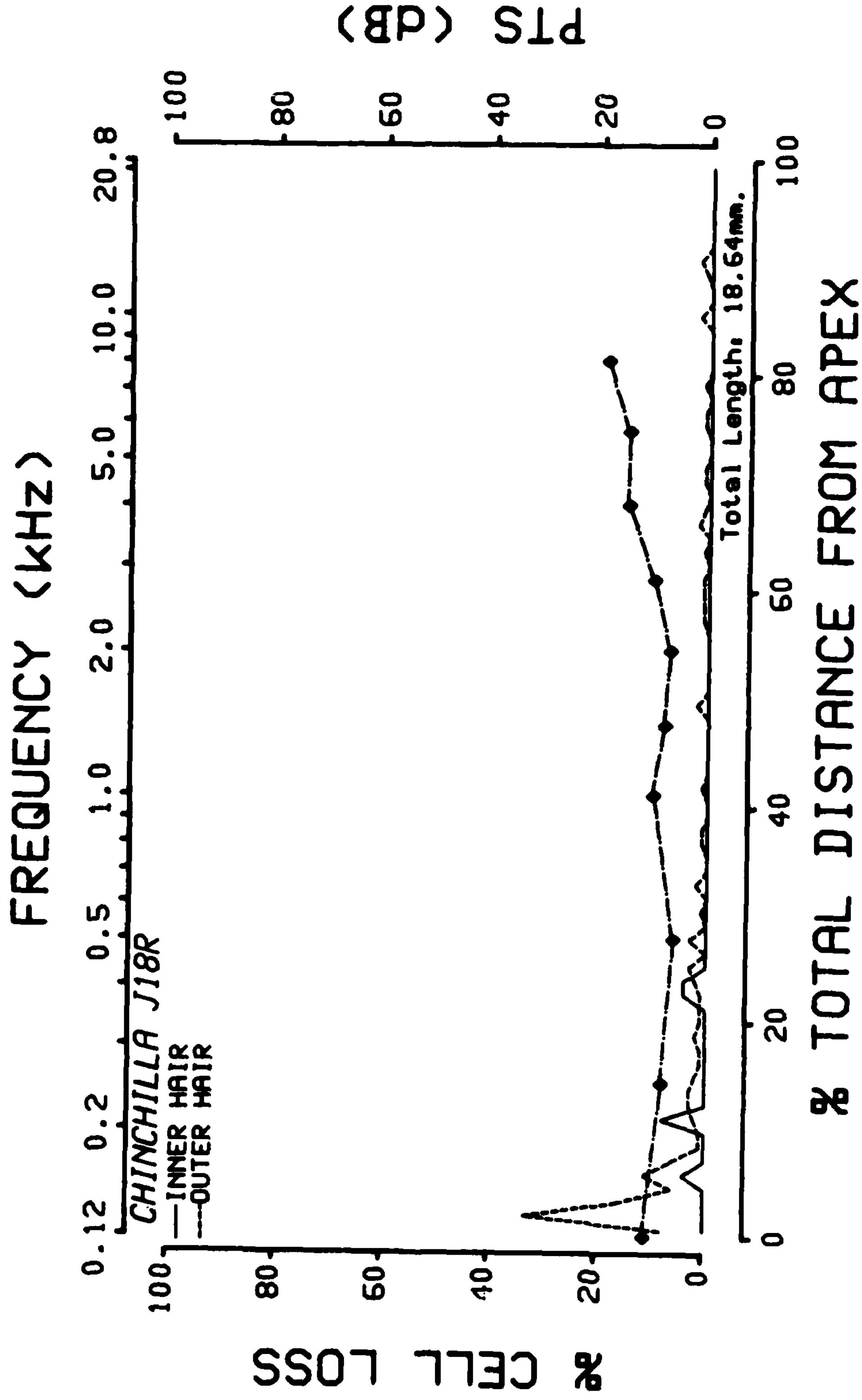
Group C - Exposure Condition: 10X @ 139 dB

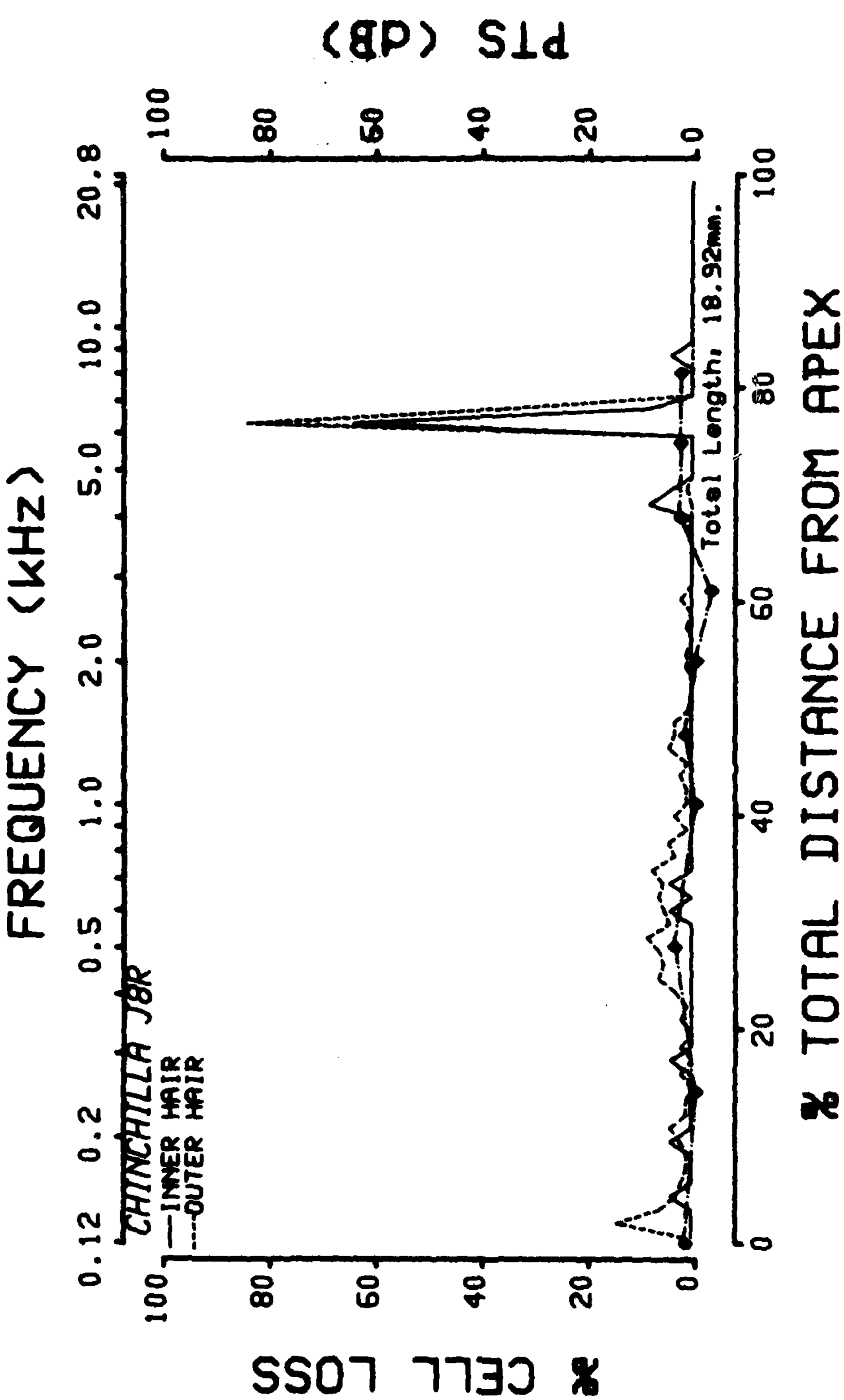
Animals: J10R*
J18R
J8R
J23BR
J17R
J18BR

*R refers to the right ear

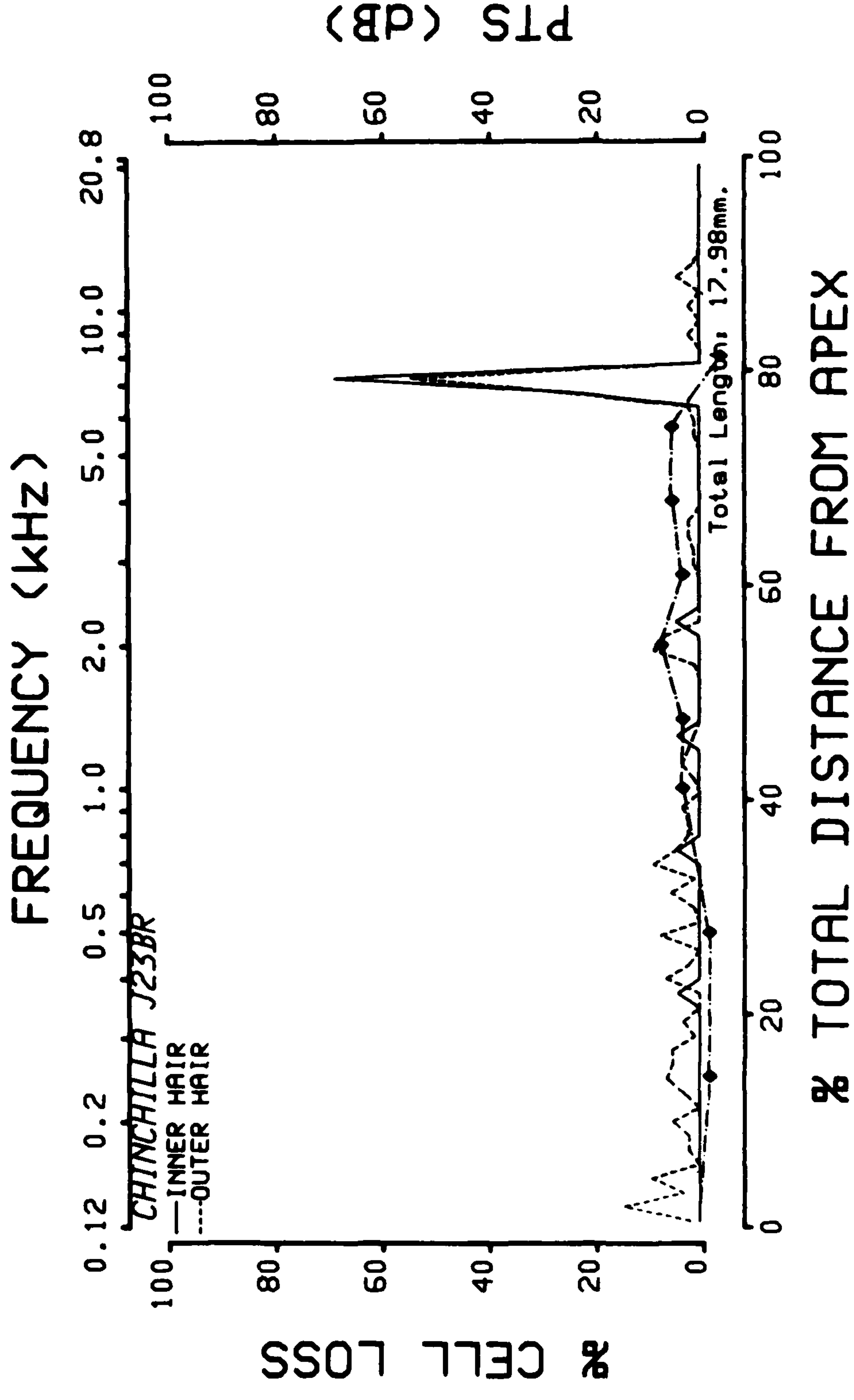


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA J10R
—INNER HAIR
---OUTER HAIR
Total Length: 18.40mm.
% CELL LOSS
% TOTAL DISTANCE FROM APEX

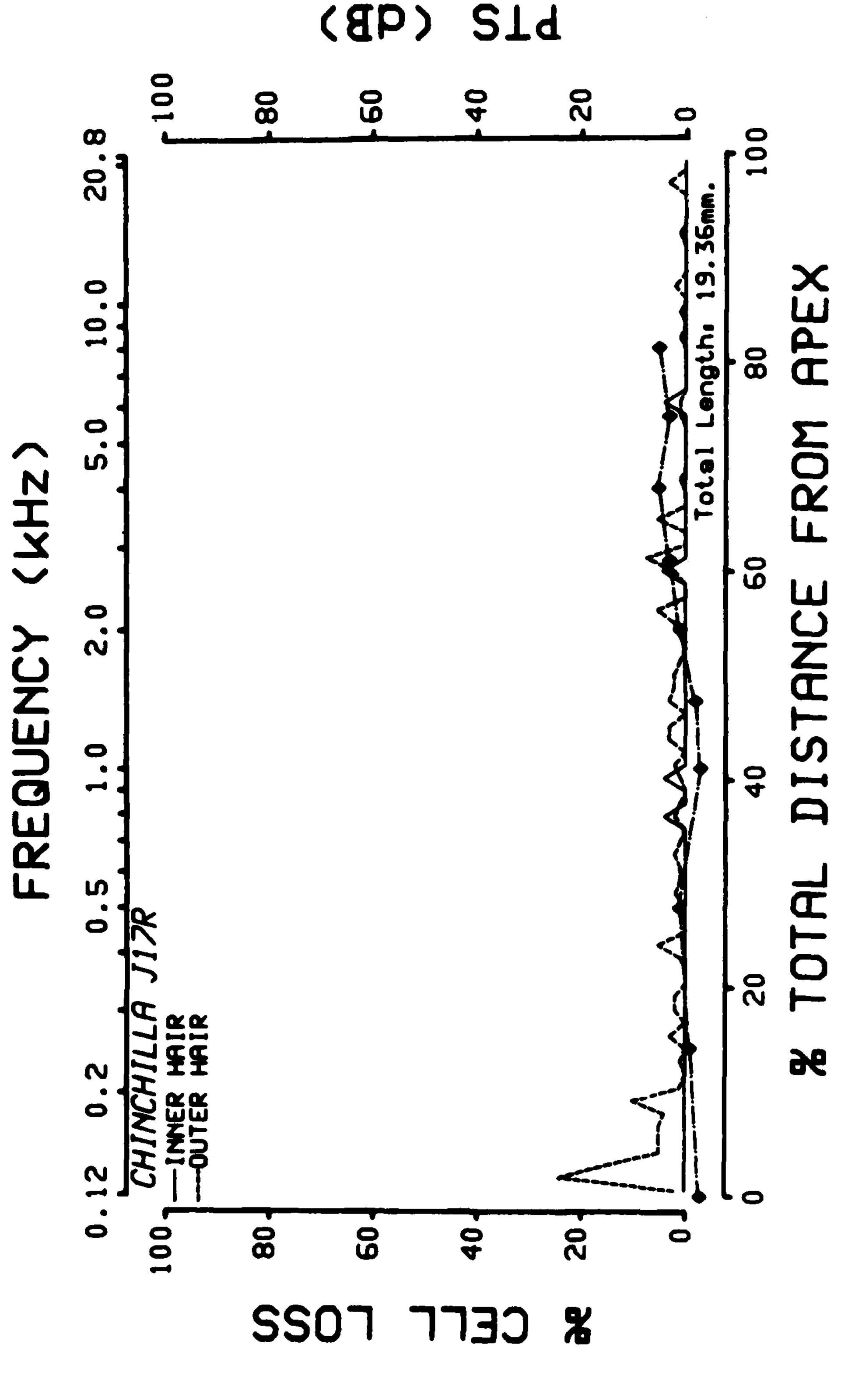

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA J18R
—INNER HAIR
--OUTER HAIR
Total Length: 18.64mm.
% CELL LOSS
100
80
60
40
20
0
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

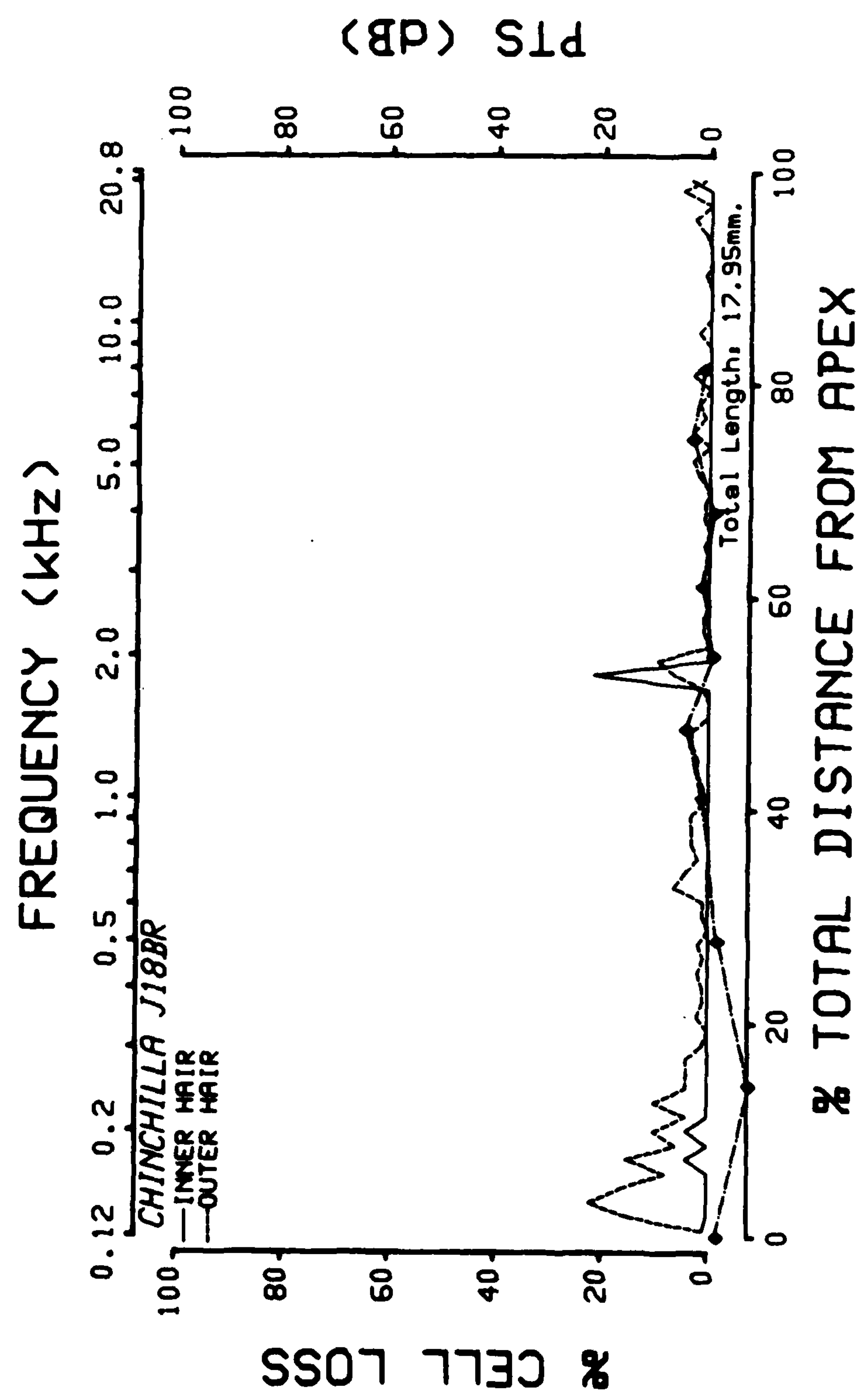


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA J8R
— INNER HAIR
--- OUTER HAIR
Total Length: 18.92mm.
% CELL LOSS
PTS (dB)
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX
Total Length: 17.98mm.
CHINCHILLA J23BR
INNER HAIR
OUTER HAIR

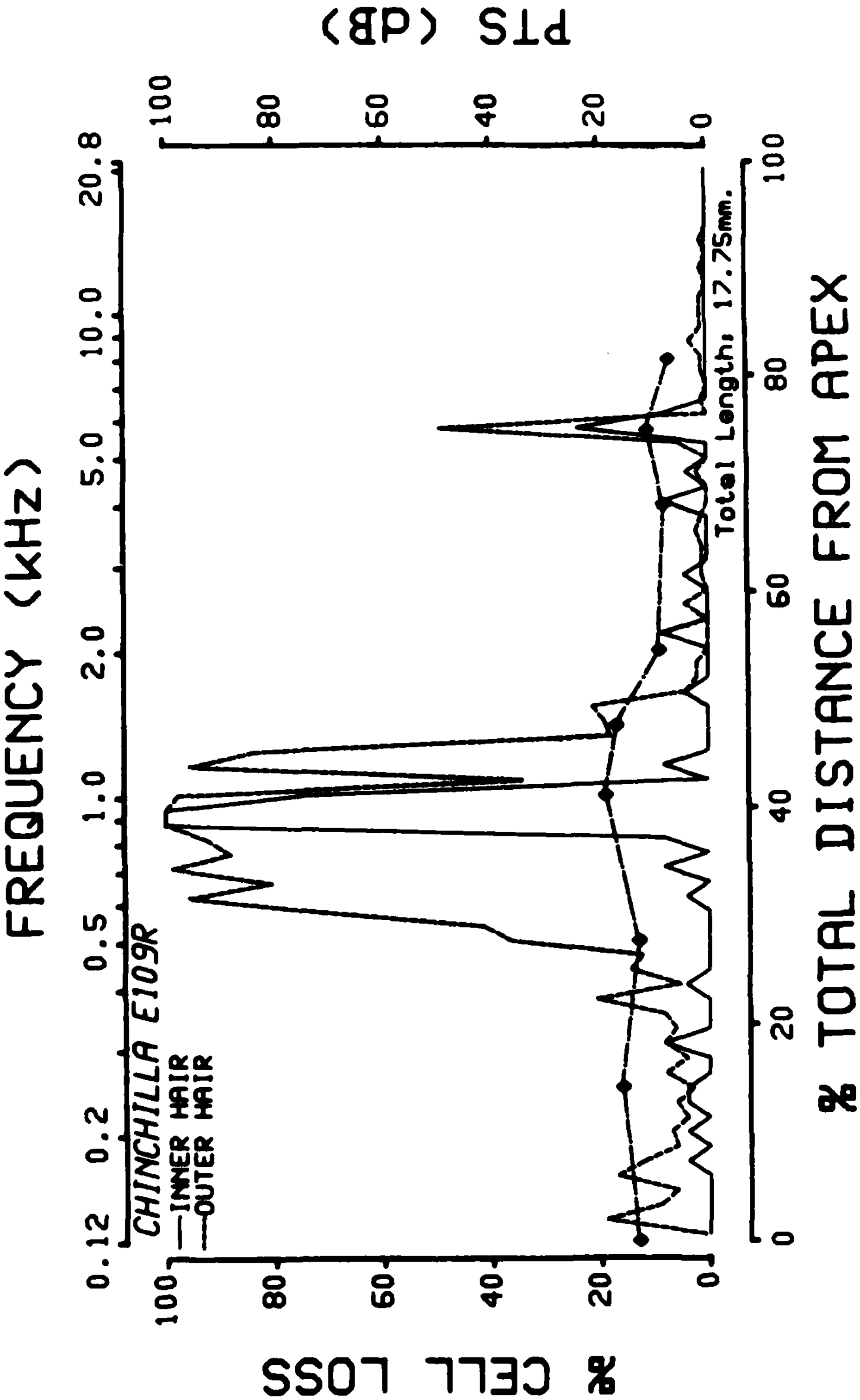

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
% CELL LOSS
100
80
60
40
20
0
CHINCHILLA J17R
—INNER HAIR
--OUTER HAIR
Total Length: 19.36mm.
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

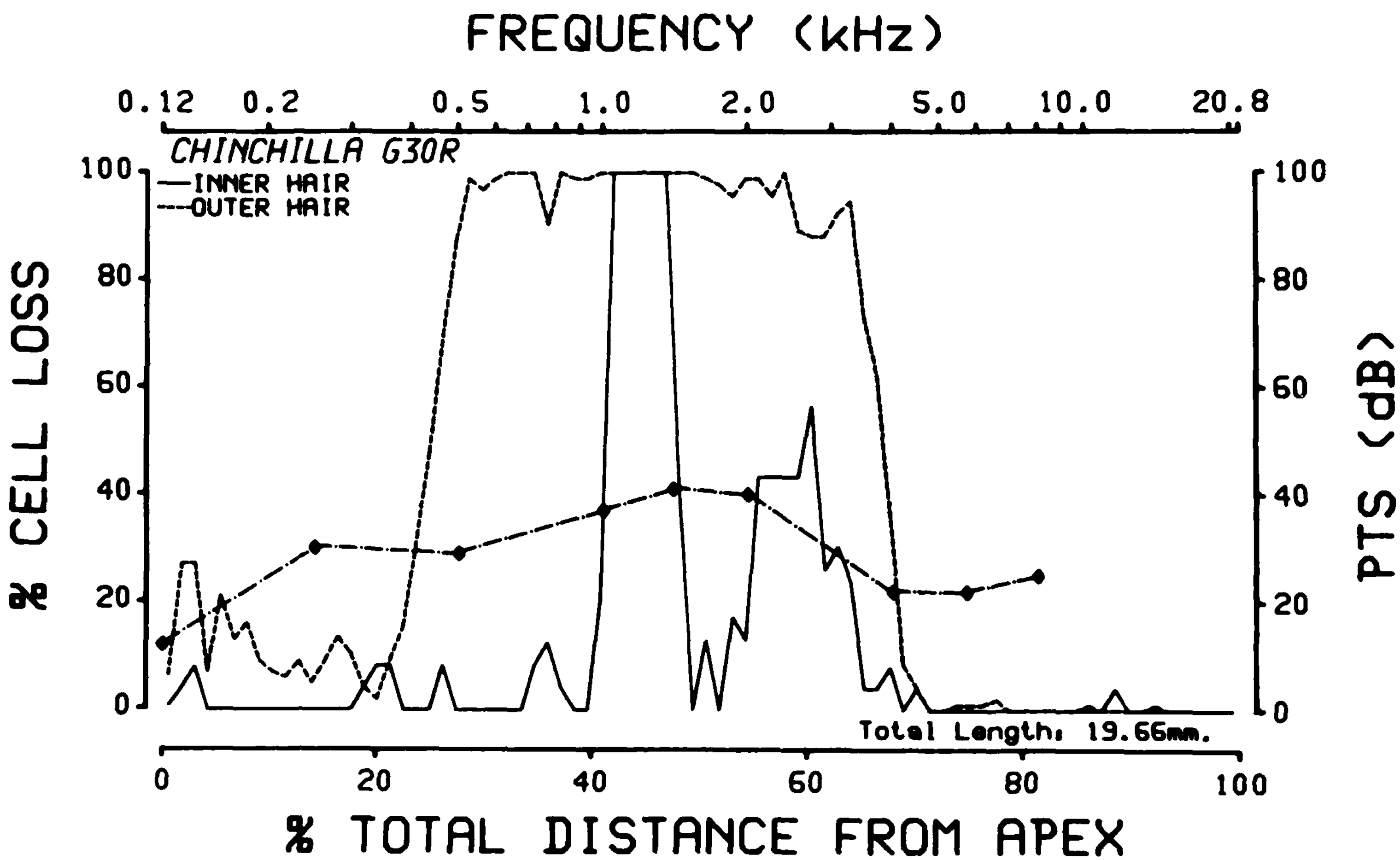

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
0
20
40
60
80
100
CHINCHILLA J18BR
—INNER HAIR
—OUTER HAIR
Total Length: 17.95mm.
% TOTAL DISTANCE FROM APEX

Group D - Exposure Condition: 100X @ 139 dB

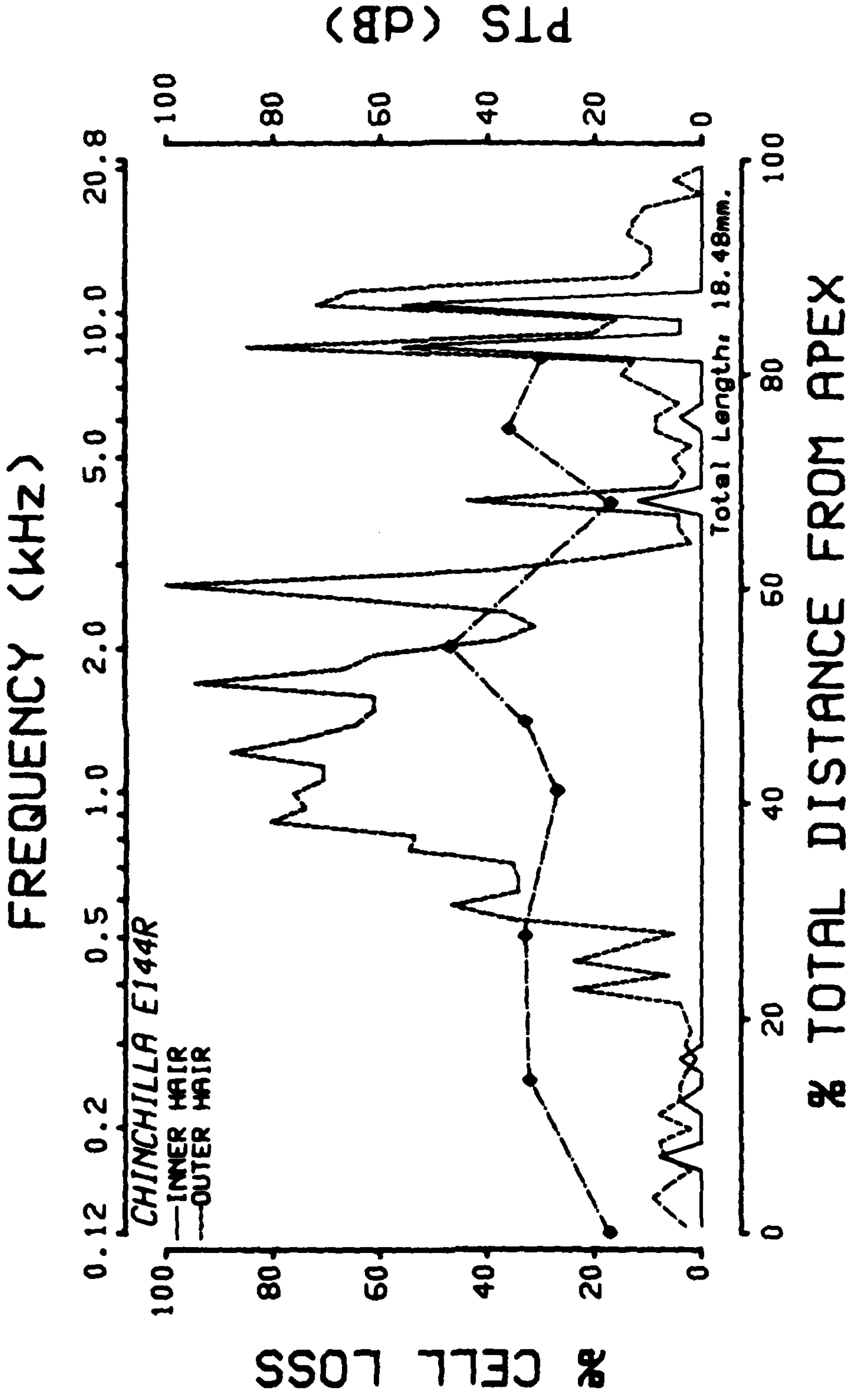
Animals: E109R*
G30R
E144R
H16R
H1R
H42R

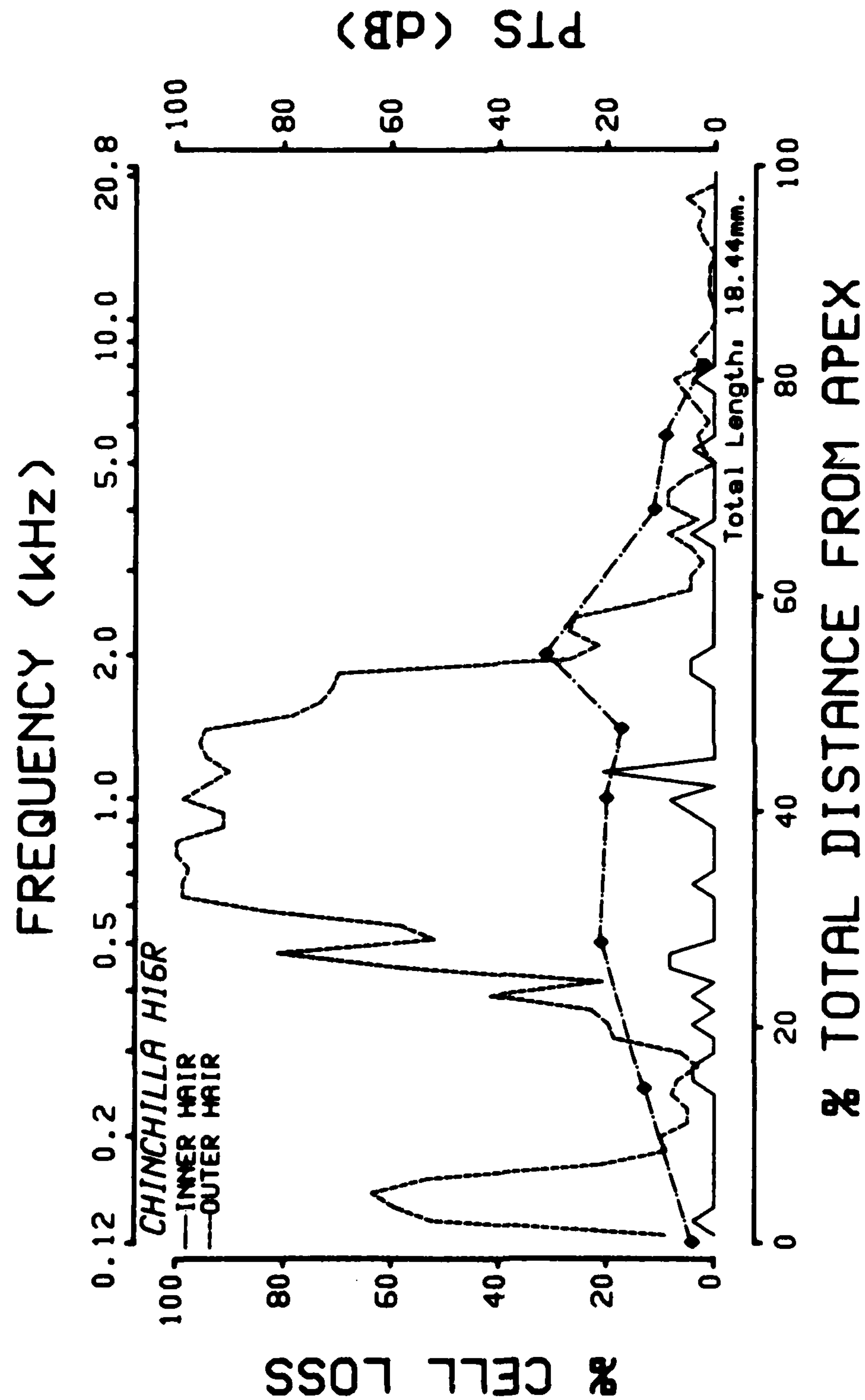
*R refers to the right ear

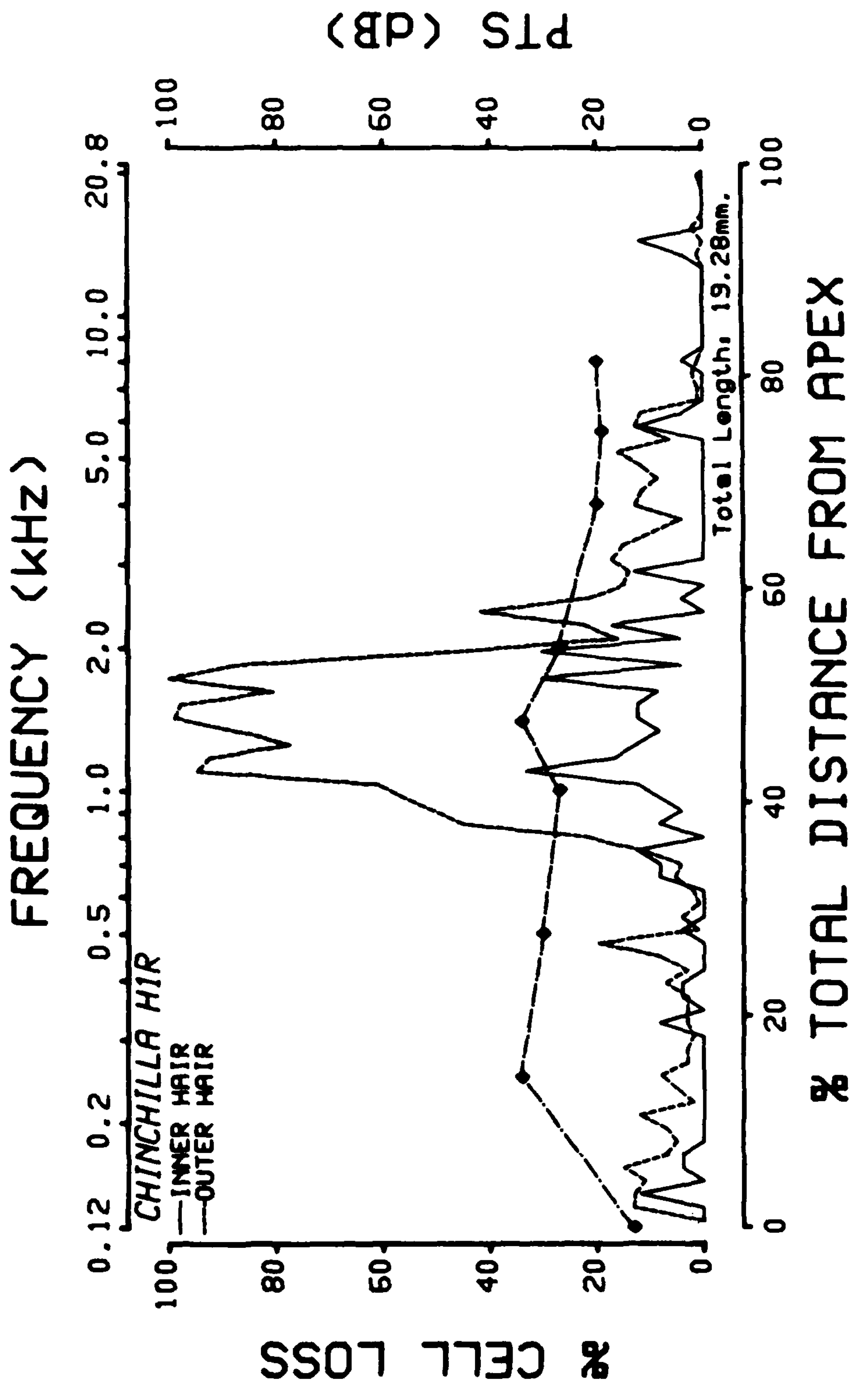

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA E109R
—INNER HAIR
—OUTER HAIR
Total Length: 17.75mm.
0
20
40
60
80
100

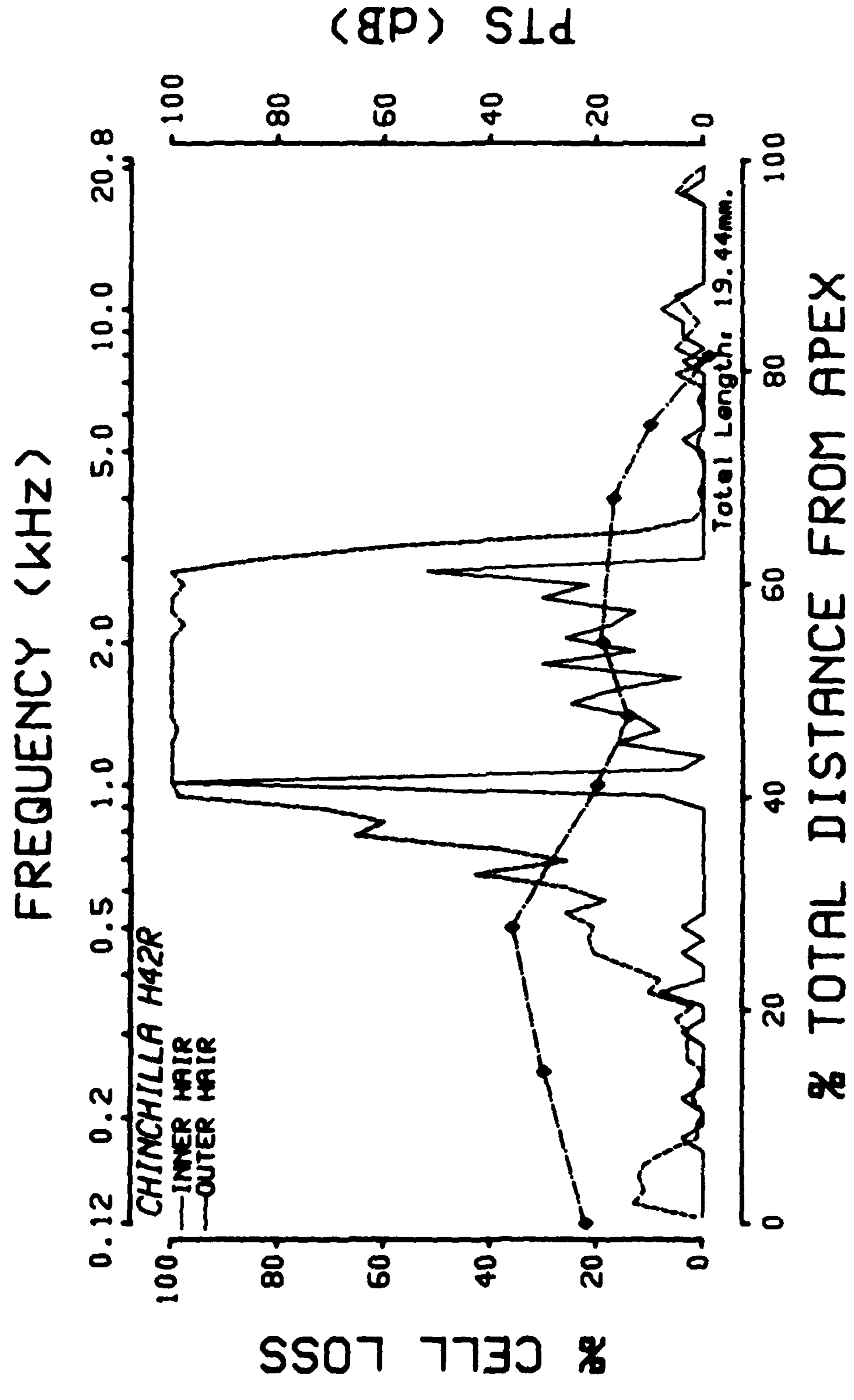


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G30R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length: 19.66mm.
% TOTAL DISTANCE FROM APEX


CHINCHILLA E144R
—INNER HAIR
—OUTER HAIR
FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
100 80 60 40 20 0
Total Length: 18.48mm.
% TOTAL DISTANCE FROM APEX
0 20 40 60 80 100


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
% CELL LOSS
100
80
60
40
20
0
CHINCHILLA H16R
INNER HAIR
OUTER HAIR
Total Length: 18.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

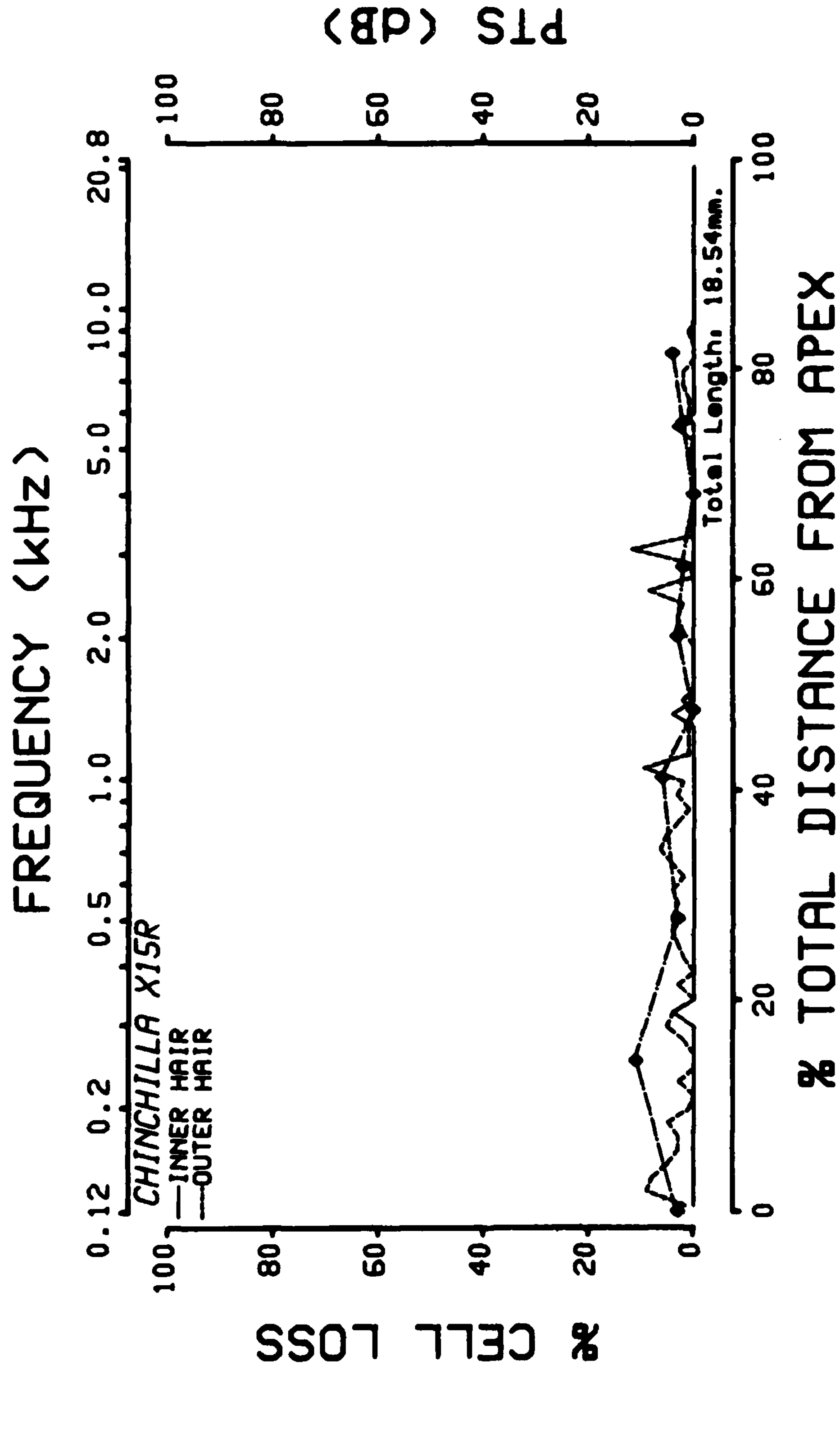

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
0
20
40
60
80
100
CHINCHILLA HIR
—INNER HAIR
—OUTER HAIR
Total Length: 19.28mm.
% TOTAL DISTANCE FROM APEX

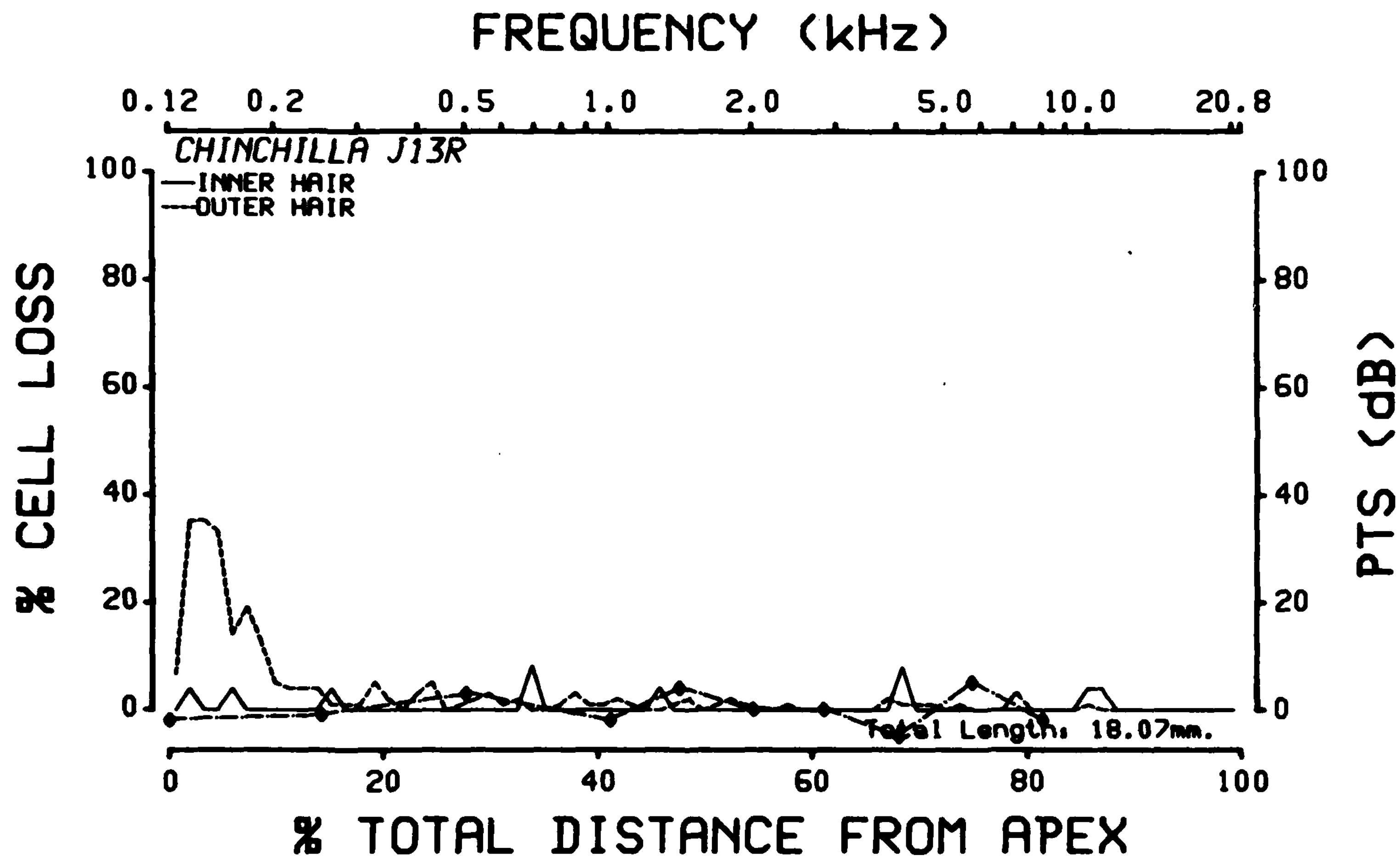

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
CHINCHILLA H42R
—INNER HAIR
—OUTER HAIR
Total Length: 19.44mm.
% CELL LOSS
% TOTAL DISTANCE FROM APEX

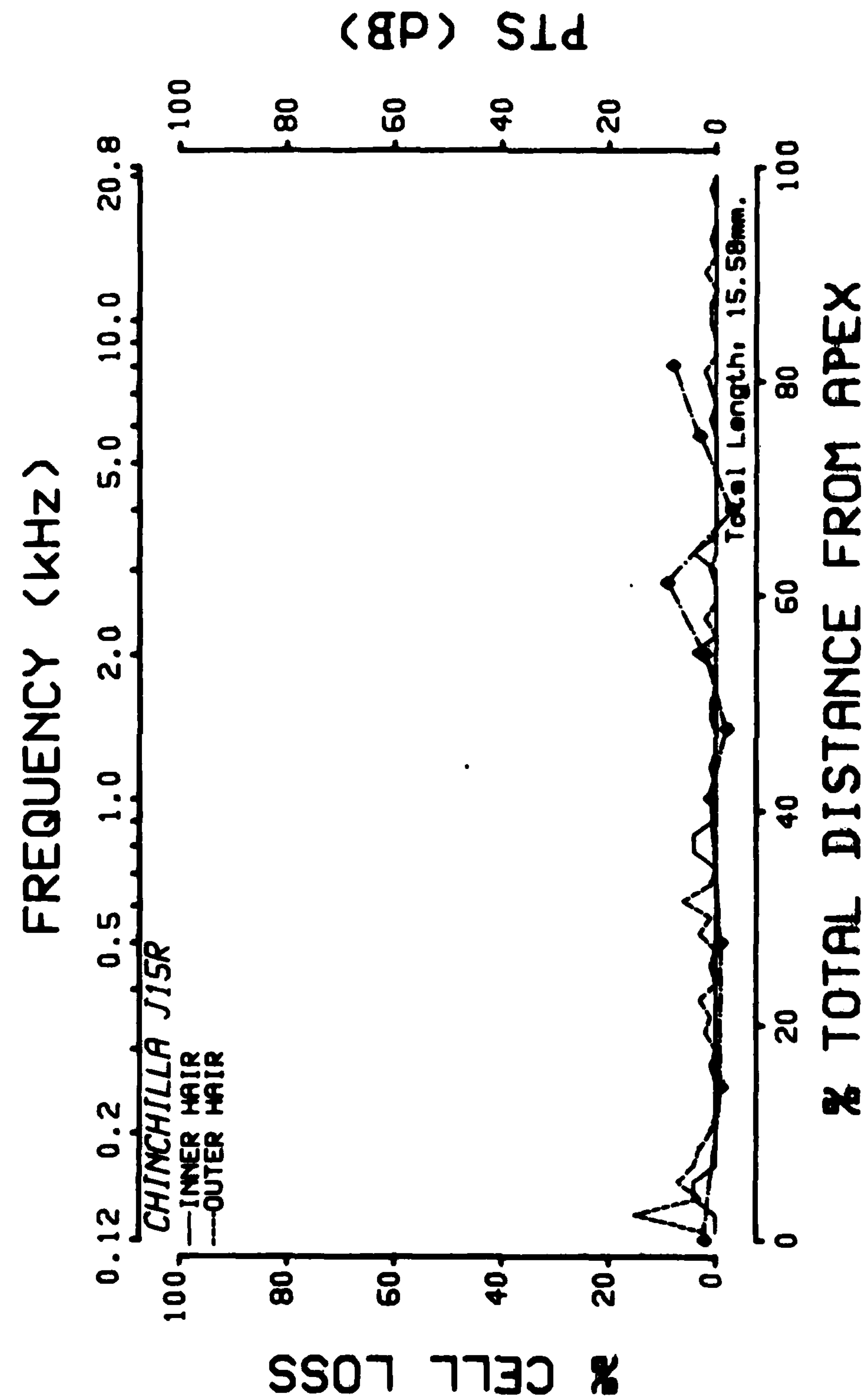
Group E - Exposure Condition: 1X @ 147 dB

Animals: X15R*
J13R
J15R
J21R
J14AR
J20AR

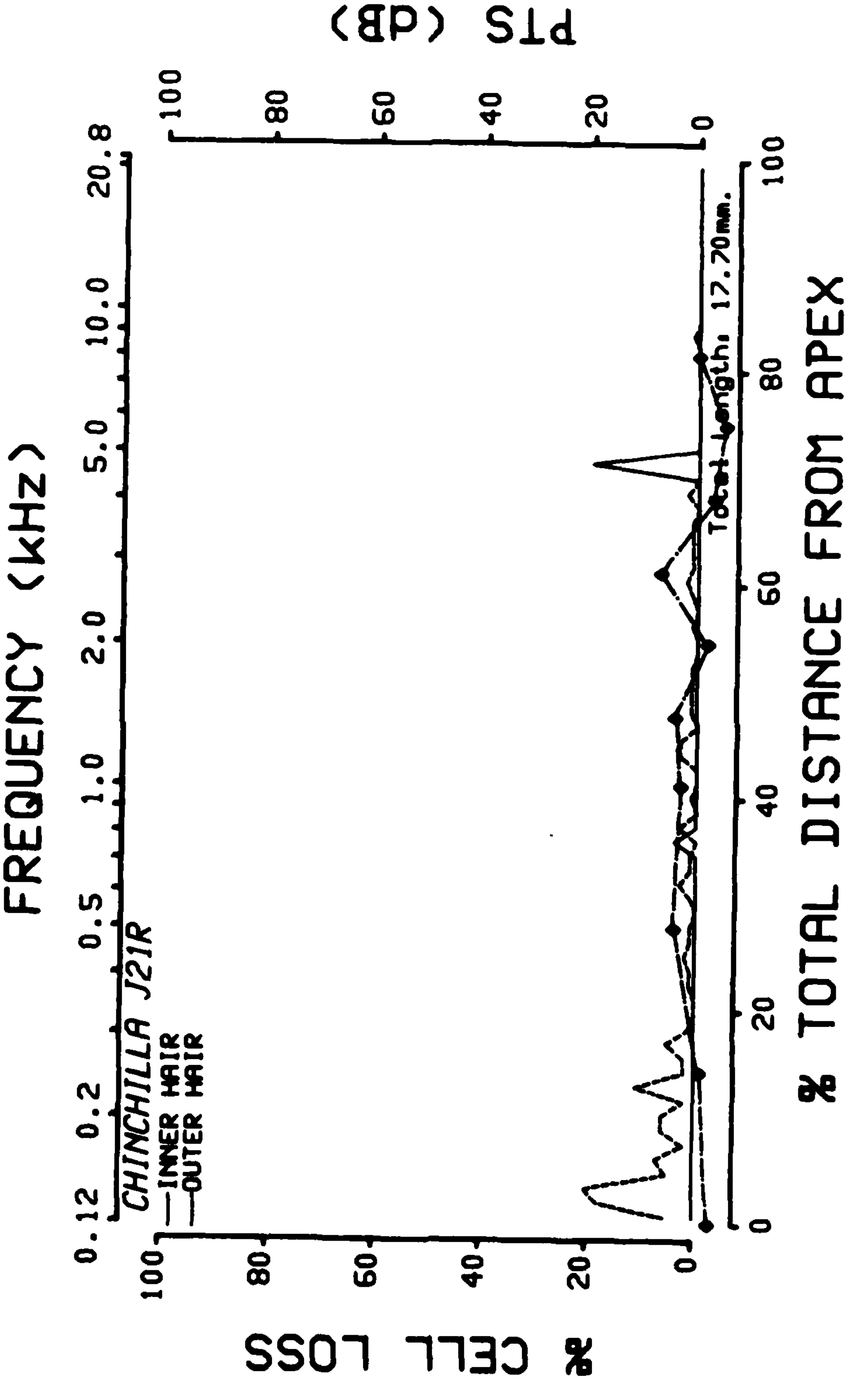
*R refers to the right ear

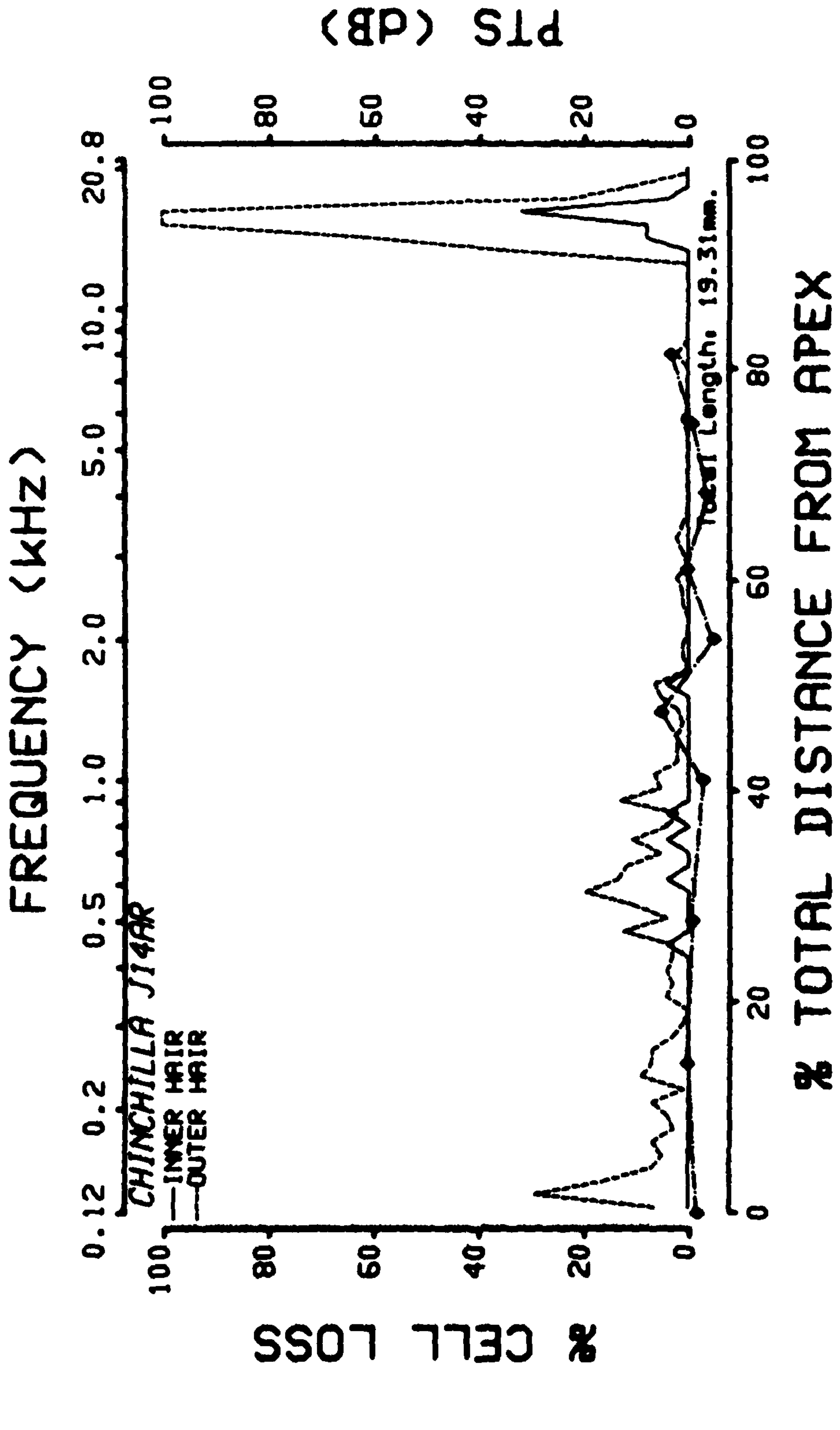

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA X15R
—INNER HAIR
—OUTER HAIR
Total Length: 18.54mm.
% CELL LOSS
100
80
60
40
20
0
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA J13R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length: 18.07mm.
% TOTAL DISTANCE FROM APEX

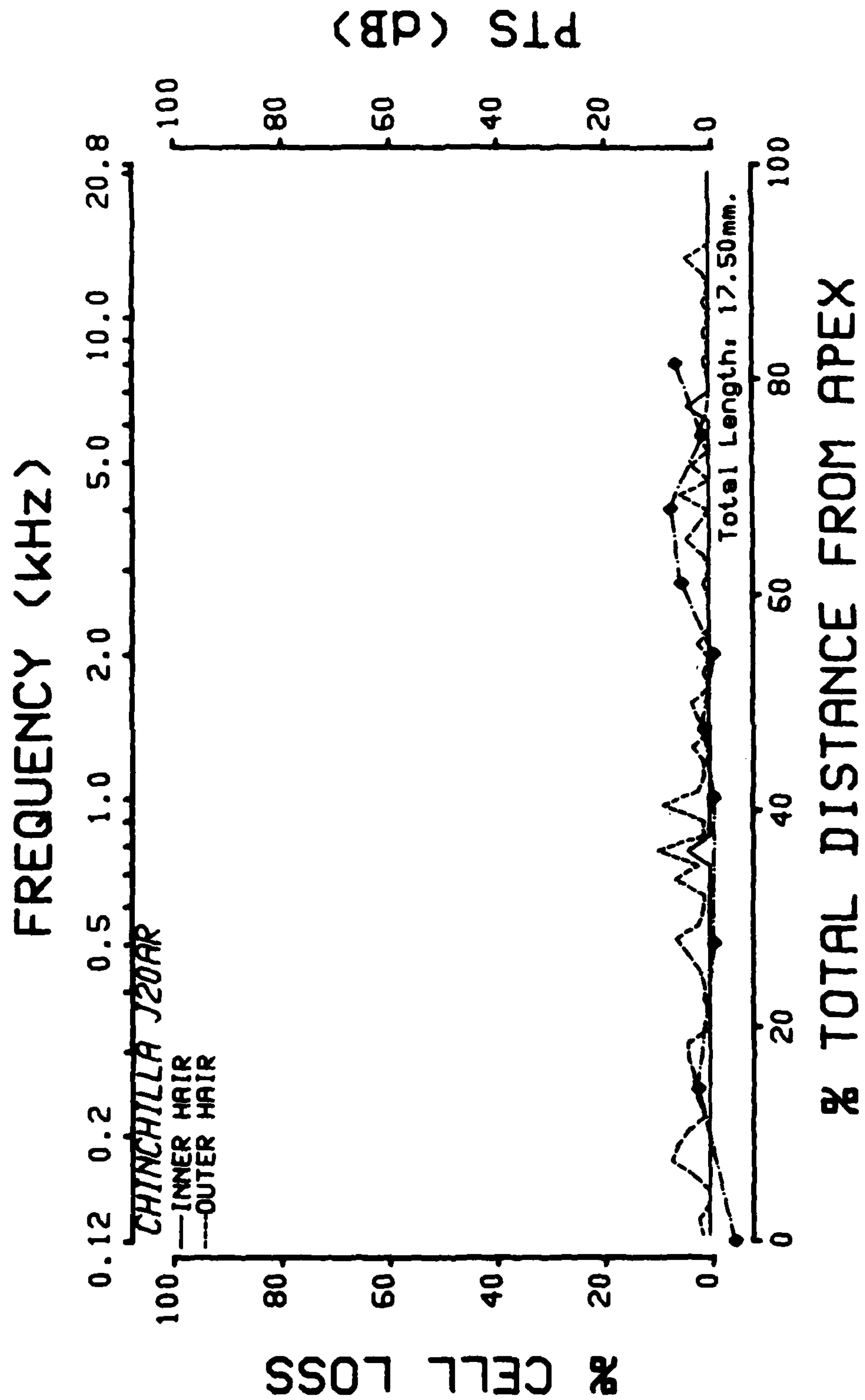


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
% CELL LOSS
CHINCHILLA J15R
INNER HAIR
OUTER HAIR
Total Length: 15.58mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA J21R
—INNER HAIR
—OUTER HAIR
Total Length: 17.70mm.
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA J14AR
INNER HAIR
OUTER HAIR
Total Length: 19.31mm.
% CELL LOSS
100
80
60
40
20
0
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100

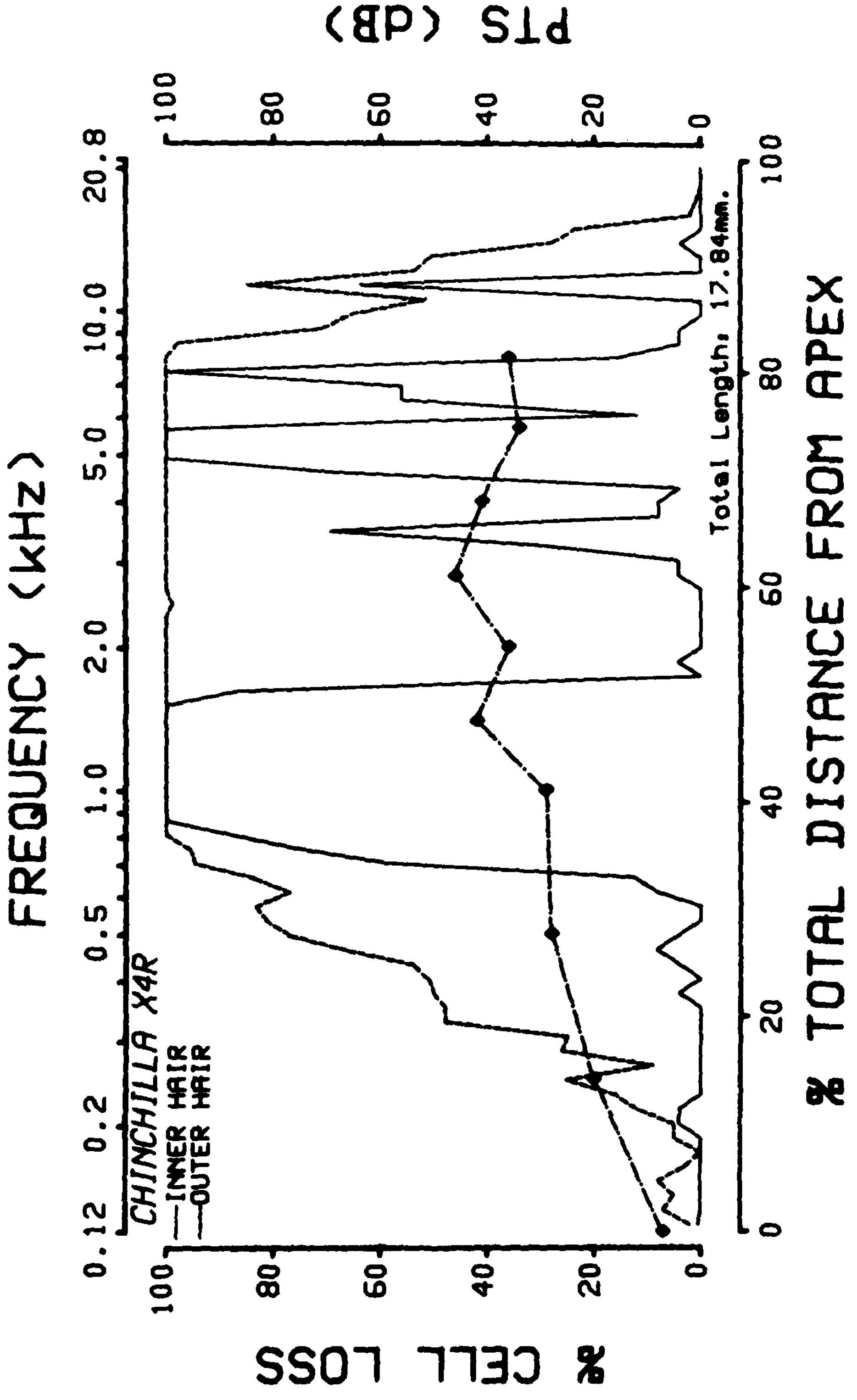


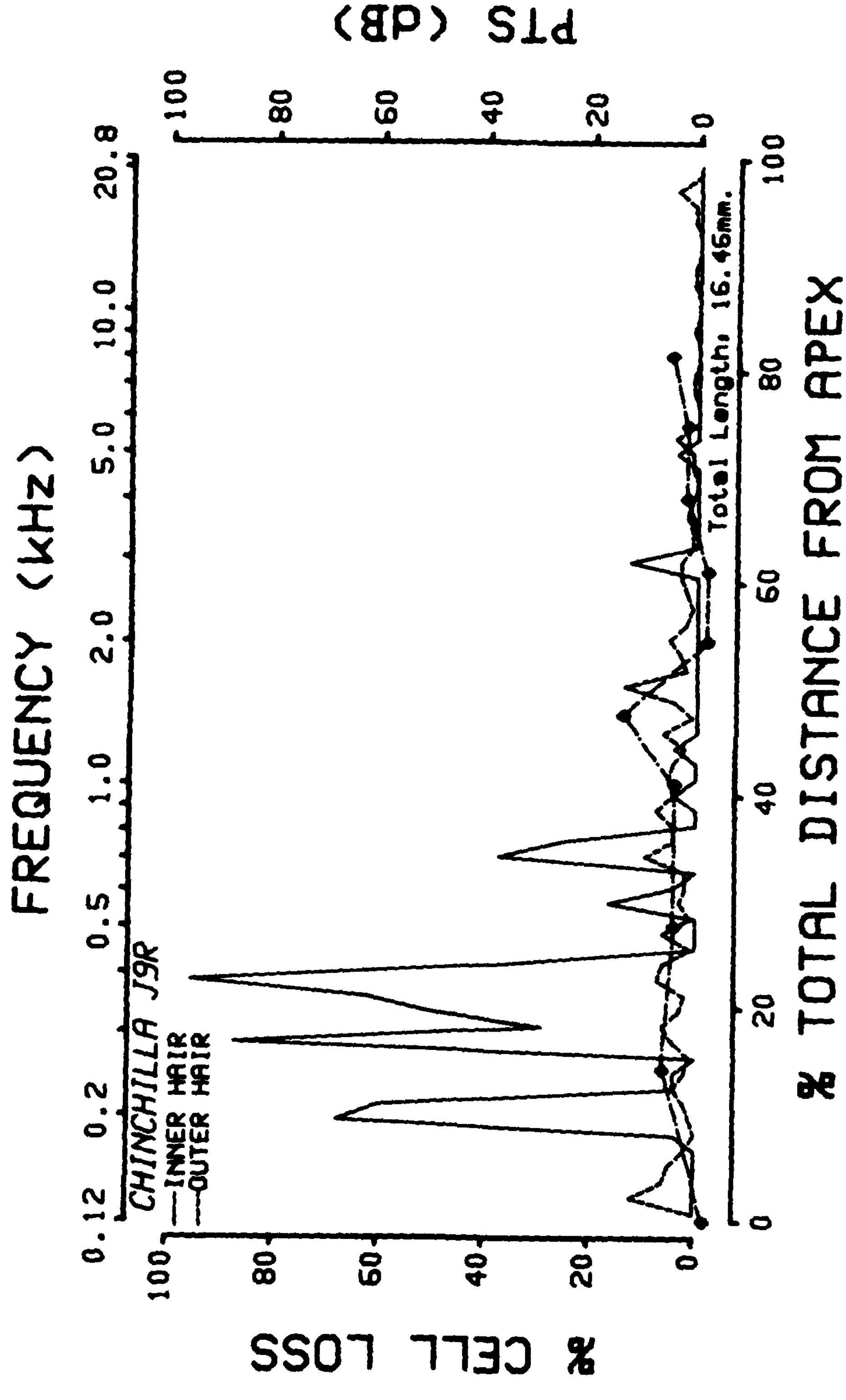
FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
PTS (dB)
100 80 60 40 20 0
% CELL LOSS
100 80 60 40 20 0
% TOTAL DISTANCE FROM APEX
0 20 40 60 80 100
CHINCHILLA J20AR
—INNER HAIR
--OUTER HAIR
Total Length: 17.50mm.

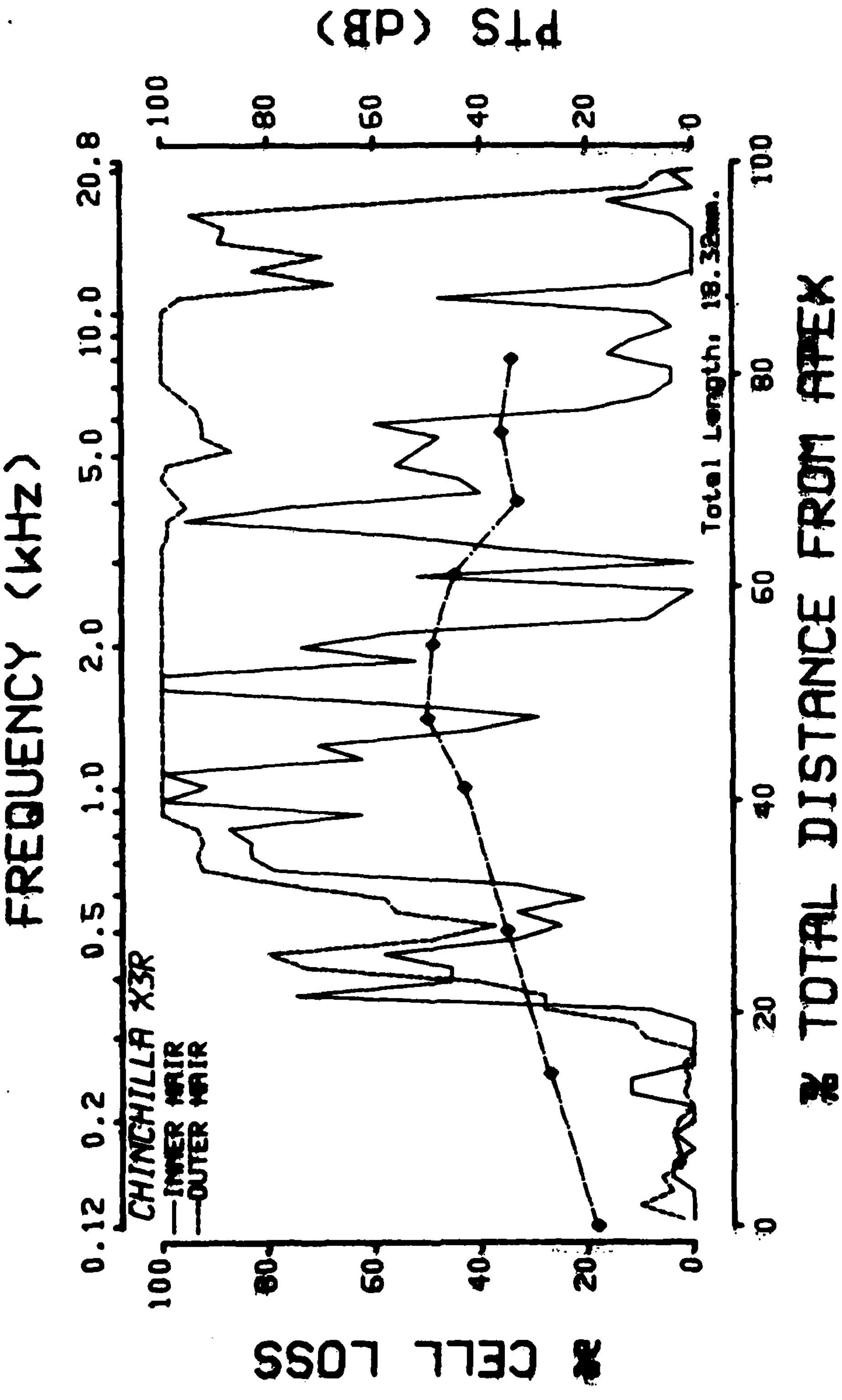
Group F - Exposure Condition: 10X @ 147 dB

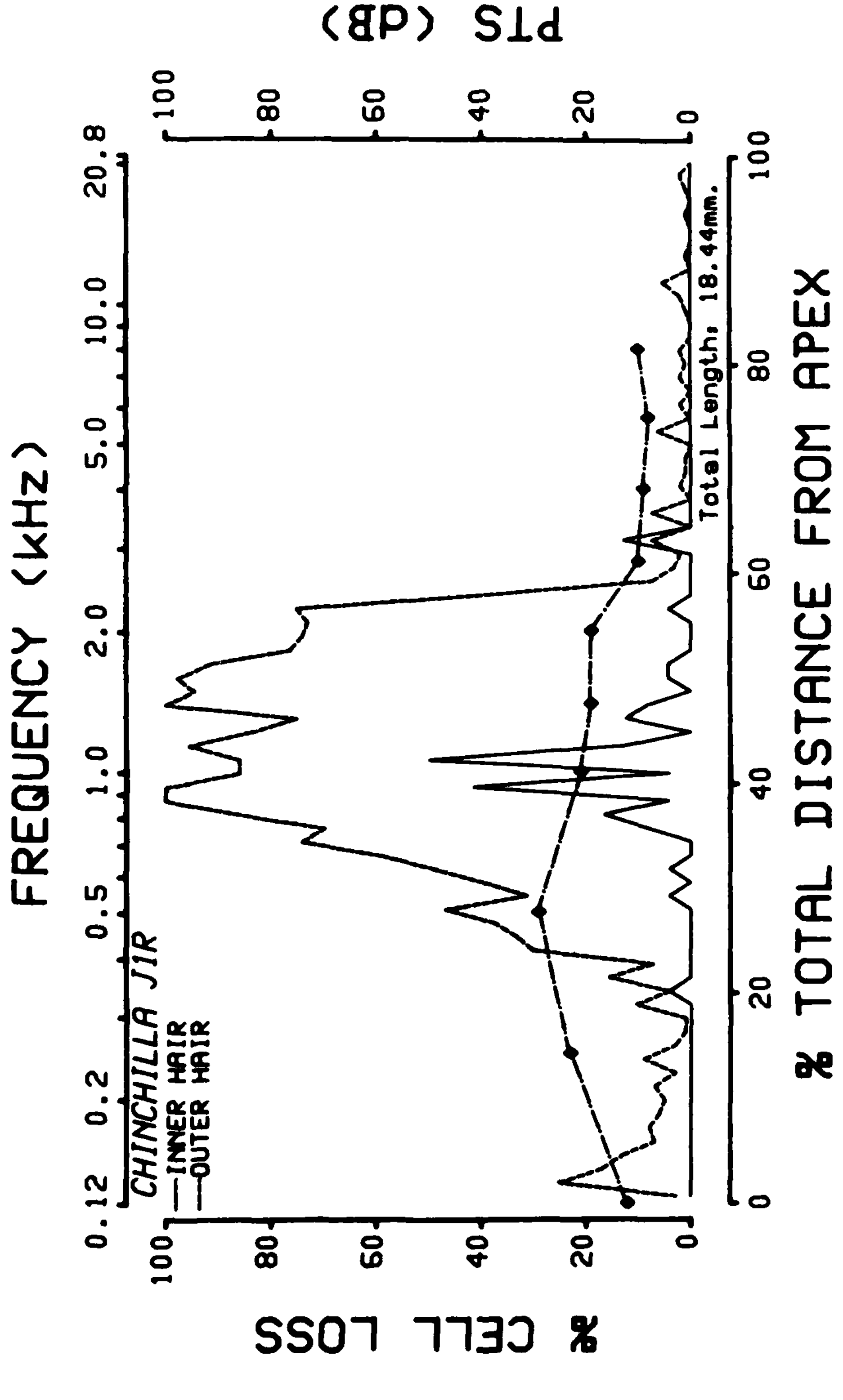
Animals: X4R*
J9R
X3R
J1R
J4R
G29R

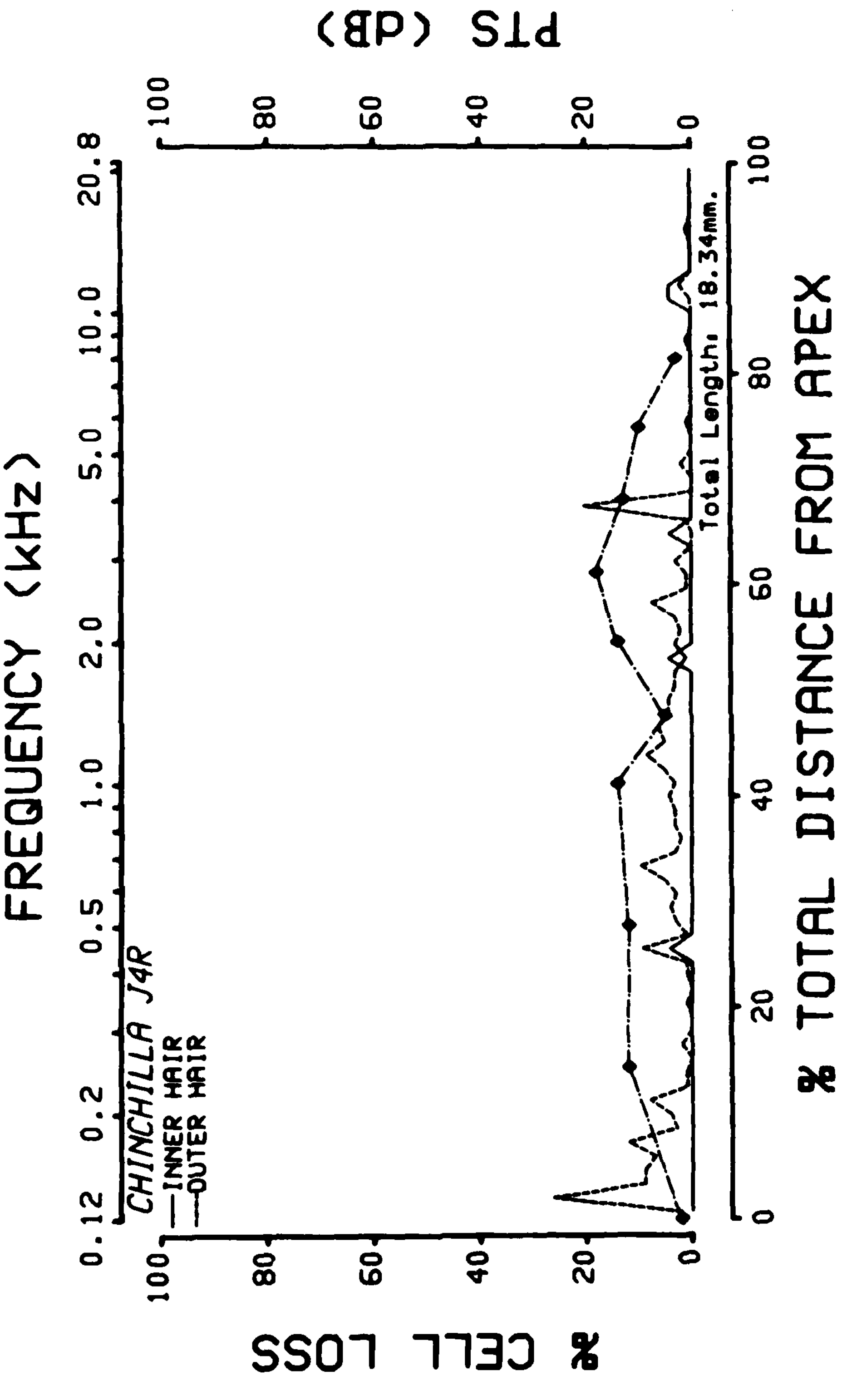
*R refers to the right ear

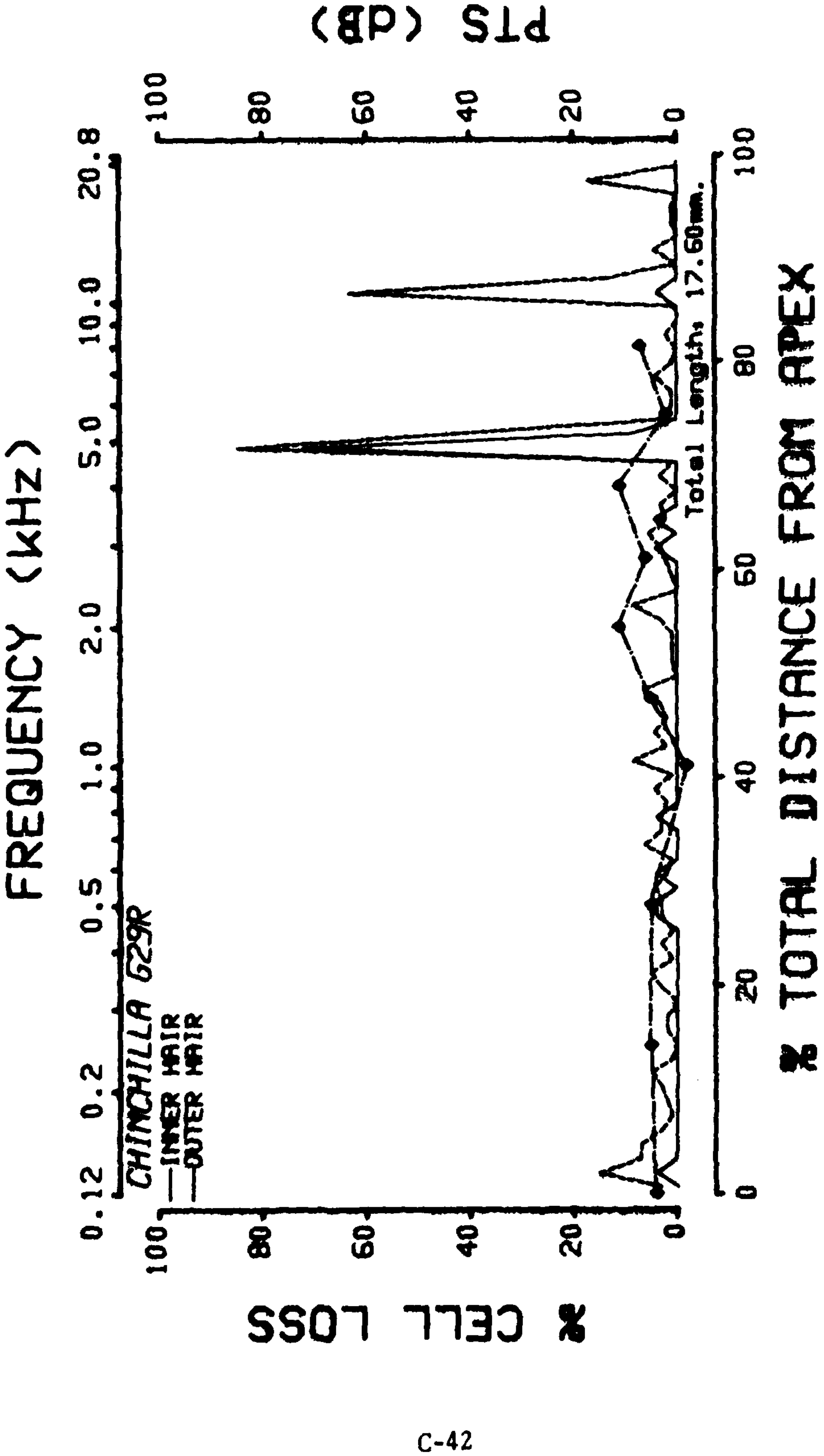

FREQUENCY (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10.0 20.8
CHINCHILLA X4R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100 80 60 40 20 0
PTS (dB)
Total Length: 17.84mm.
% TOTAL DISTANCE FROM APEX
0 20 40 60 80 100


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
CHINCHILLA J9R
—INNER HAIR
—OUTER HAIR
Total Length: 16.46mm.
% CELL LOSS
100
80
60
40
20
0
% TOTAL DISTANCE FROM APEX
0
20
40
60
80
100


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
0
20
40
60
80
100
% CELL LOSS
% TOTAL DISTANCE FROM APEX
Total Length: 18.32mm.
CHINCHILLA X3R
—INNER HAIR
—OUTER HAIR


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA J1R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
100
80
60
40
20
0
Total Length, 18.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

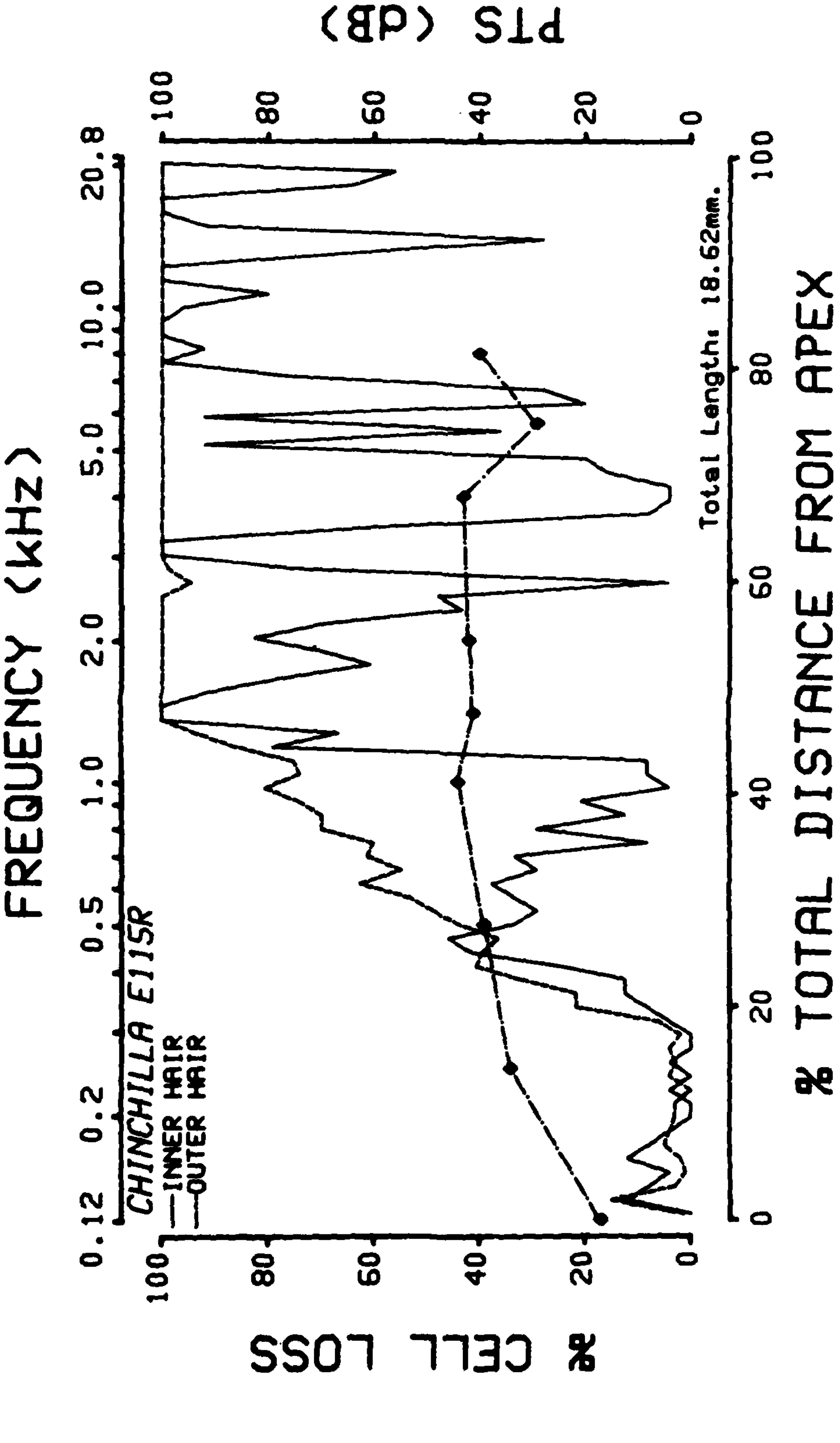

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
0
20
40
60
80
100
% CELL LOSS
% TOTAL DISTANCE FROM APEX
CHINCHILLA J4R
—INNER HAIR
—OUTER HAIR
Total Length: 18.34mm.

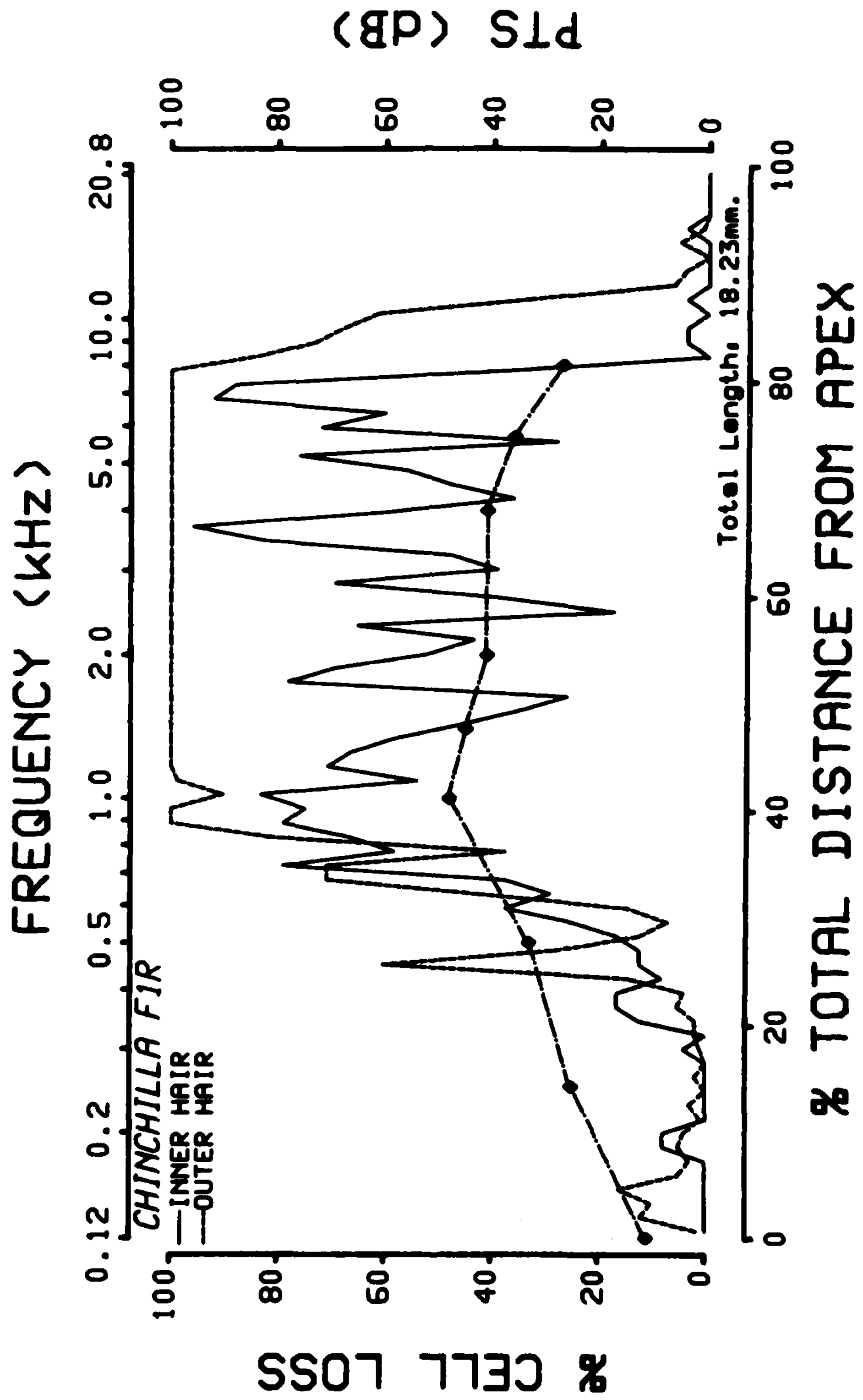

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
0
20
40
60
80
100
CHINCHILLA G29R
—INNER HAIR
—OUTER HAIR
Total Length, 17.60mm.
% TOTAL DISTANCE FROM APEX

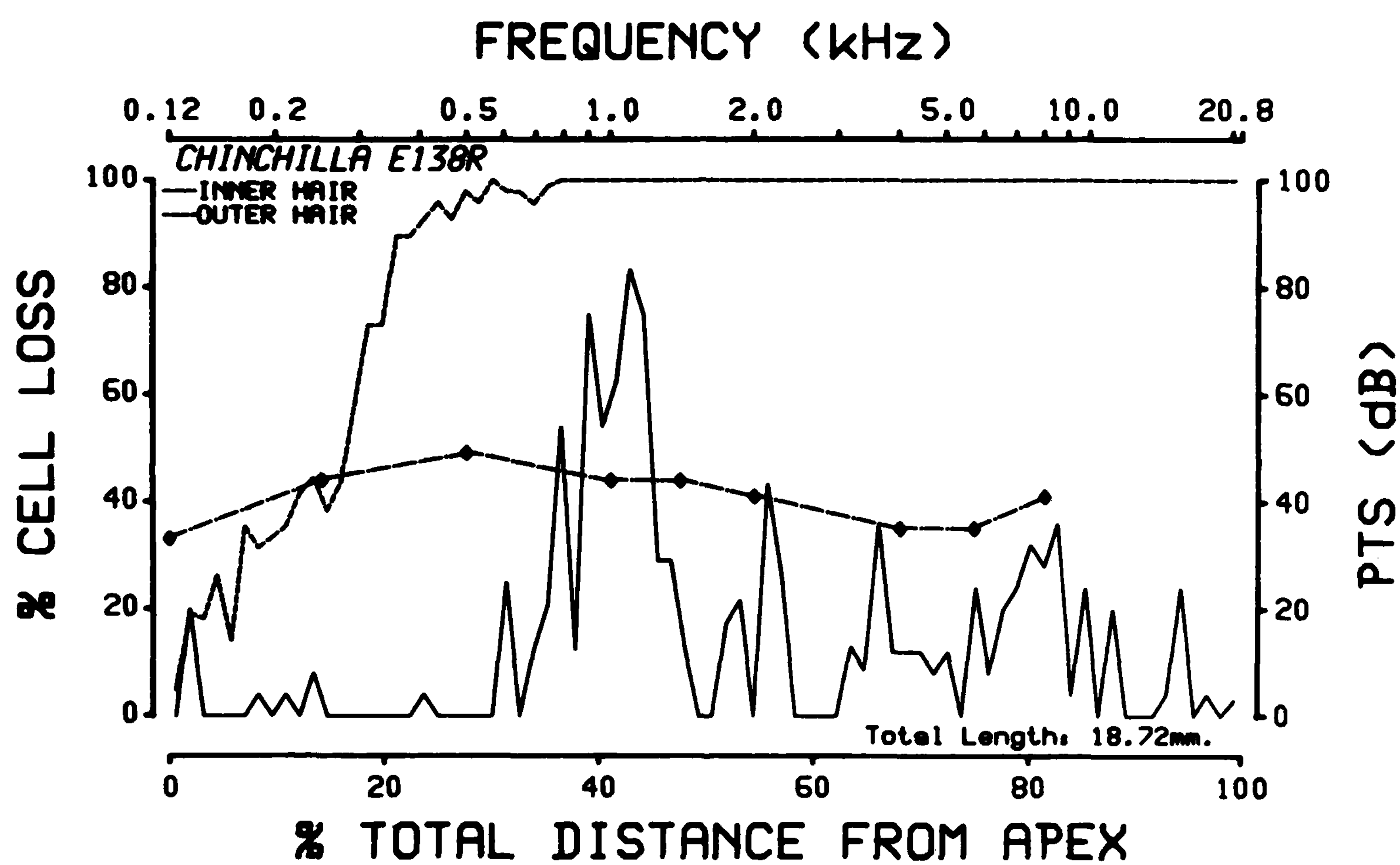
Group G - Exposure Condition: 100X @ 147 dB

Animals: E115R*
F1R
E138R
G2R
G20R
G5R

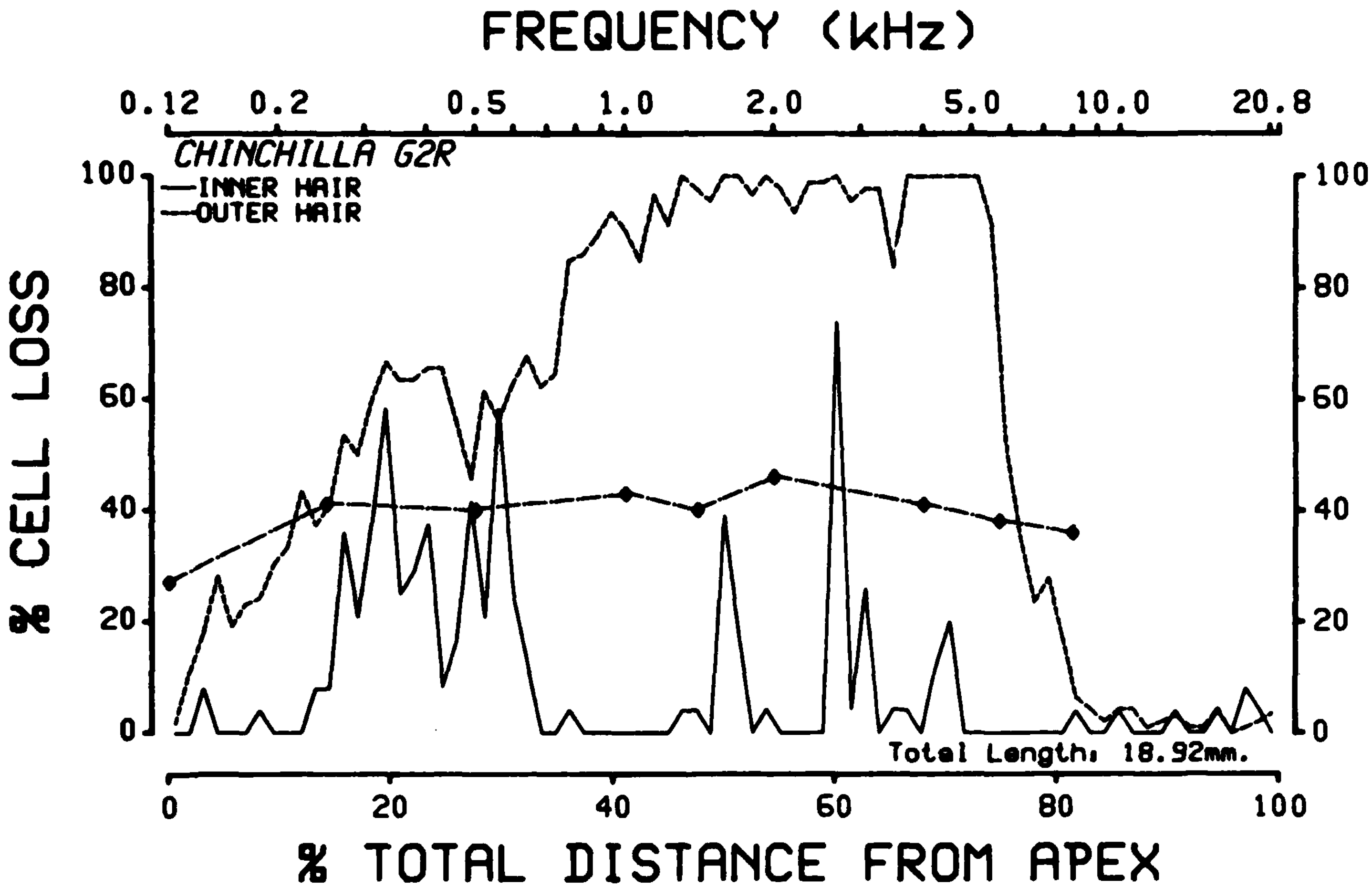
*R refers to the right ear


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
100
80
60
40
20
0
CHINCHILLA E115R
—INNER HAIR
—OUTER HAIR
Total Length: 18.62mm.
% TOTAL DISTANCE FROM APEX

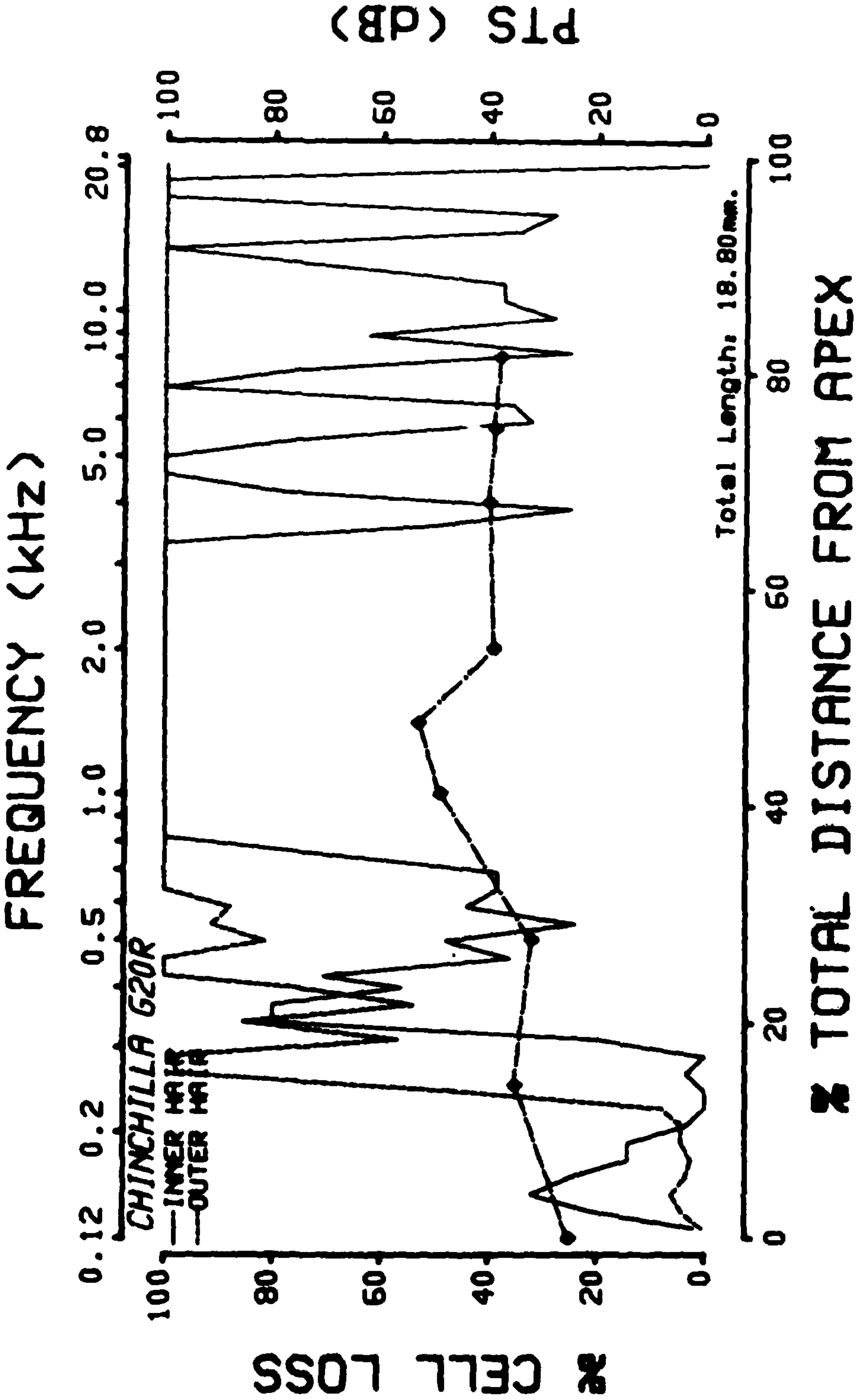

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
100
80
60
40
20
0
% CELL LOSS
CHINCHILLA F1R
—INNER HAIR
—OUTER HAIR
Total Length, 18.23mm.
% TOTAL DISTANCE FROM APEX

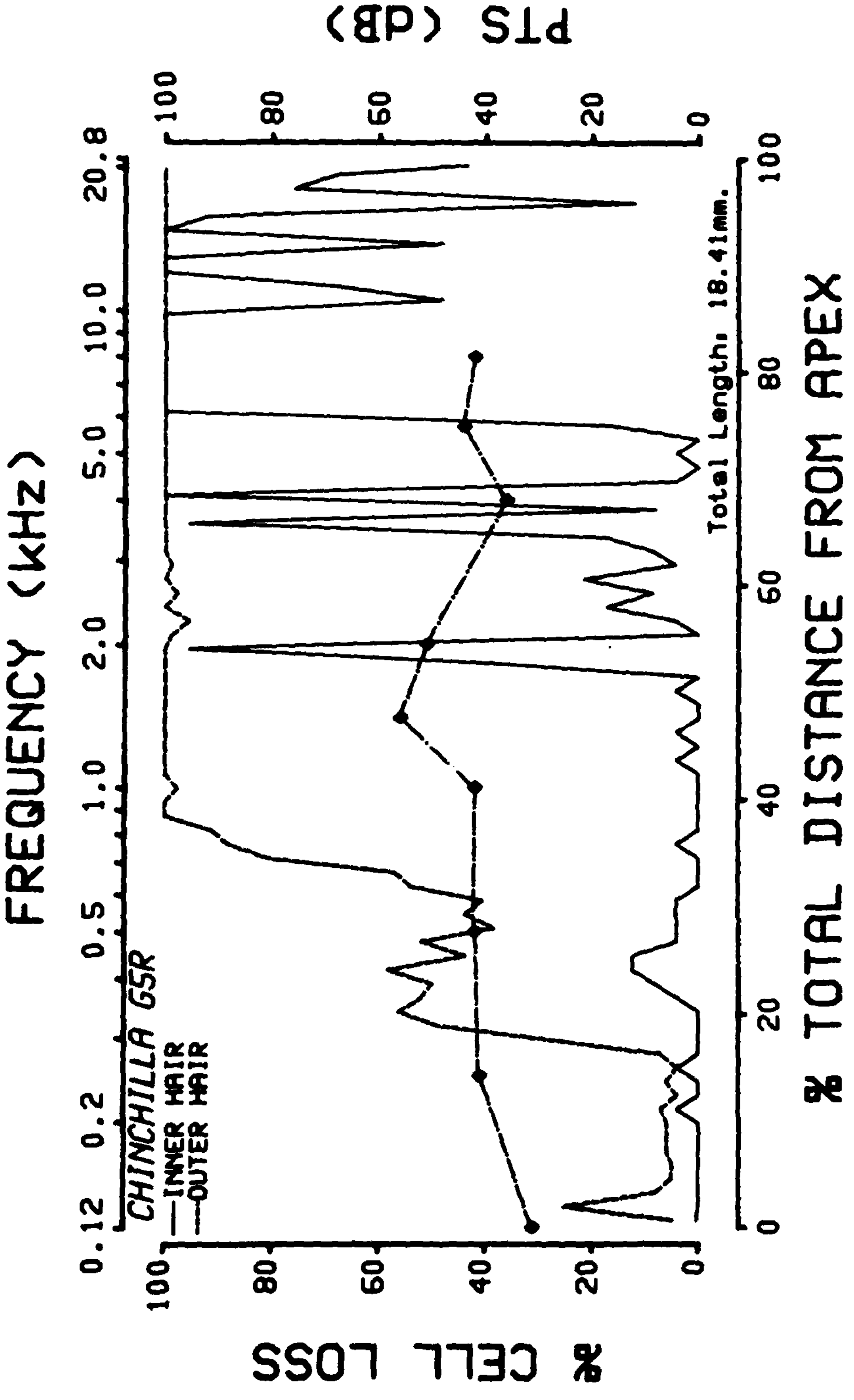


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E138R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length: 18.72mm.
% TOTAL DISTANCE FROM APEX



FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G2R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length: 18.92mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
PTS (dB)
% CELL LOSS
% TOTAL DISTANCE FROM APEX
Total Length: 18.80mm.
CHINCHILLA G20R
INNER HAIR
OUTER HAIR


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G5R
—INNER HAIR
—OUTER HAIR
% CELL LOSS
100
80
60
40
20
0
PTS (dB)
Total Length, 18.41mm.
% TOTAL DISTANCE FROM APEX

APPENDIX D

Summary of all the individual and group histological data presented in numerical form as raw data and averaged data. These summary figures were obtained from the detailed data that are plotted in Appendix C.

GROUP A: 100 IMPULSES @ 131 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
K7R	5	54	35	80	169
J35R	4	55	103	108	266
K5R	17	30	50	109	189
J34R	11	37	63	93	193
K105R	1	153	47	57	257
GROUP MEAN	8				215
SD	6				44

GROUP B: 100 IMPULSES @ 135 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
H184R	20	57	75	71	203
K21R	56	270	326	539	1135
K108R	11	410	415	371	1196
K103R	187	515	604	419	1538
K68R	80	214	252	320	786
K116R	9	27	24	77	128
GROUP MEAN	61				831
SD	68				569

GROUP C: 10 IMPULSES @ 139 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
J10R	5	71	76	71	218
J18R	5	48	52	106	206
J8R	27	60	78	119	257
J23BR	27	51	65	117	233
J17R	4	27	59	78	. 164
J18BR	10	50	67	108	225
GROUP MEAN	12				217
SD	12				31

GROUP D: 100 IMPULSES @ 139 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
E109R	95	445	482	439	1366
G30R	240	1160	1147	1099	3406
E144R	38	839	708	520	2067
H16R	23	876	930	658	2464
H1R	83	523	440	498	1461
H42R	109	836	780	763	2379
GROUP MEAN	98				2191
SD	77				750

GROUP E: 1 IMPULSE @ 147 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
X15R	3	60	46	58	164
J13R	10	64	108	116	288
J15R	6	27	20	43	90
J21R	6	40	62	76	178
J14AR	18	171	252	219	642
J20AR	2	34	42	63	139
GROUP MEAN	8				250
SD	6				203

GROUP F: 10 IMPULSES @ 147 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
X4R	504	1602	1594	1489	4685
J9R	148	55	40	91	186
X3R	607	1730	1676	1534	4940
J1R	47	785	728	492	2005
J4R	5	31	88	125	244
G29R	28	127	128	154	409
GROUP MEAN	223				2078
SD	264				2224

GROUP G: 100 IMPULSES @ 147 dB

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
E115R	841	1831	1767	1475	5073
F1R	580	1307	1298	1275	3880
E138R	258	2191	2083	2110	6384
G2R	168	1694	1435	1059	4188
G20R	1049	2115	2013	1961	6089
G5R	513	1920	1763	1735	5418
GROUP MEAN	568				5740
SD	336				1130

THE MEAN NUMBER OF INNER & OUTER HAIR CELLS IN A 0.24mm. SAMPLING WINDOW OF THE COCHLEA AT THE LOCATIONS INDICATED. THESE FIGURES WERE CALCULATED USING A POPULATION OF 30 NORMAL CHINCHILLAS, AND SERVED AS A REFERENCE FIGURE IN THE COMPUTATION OF THE PERCENTAGE OF MISSING SENSORY CELLS.

COCHLEAR LOCATION % DISTANCE FROM APEX	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS
0 - 17	25	33	33	33
17 - 33	24	32	32	32
33 - 50	24	31	31	31
50 - 67	23	31	31	31
67 - 83	25	31	31	31
83 - 100	25	31	31	31

GROUP A: 100 IMPULSES @ 131 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	1.5	10.4
0.25 kHz	0.5	3.9
0.5 kHz	0.3	3.7
1 kHz	0.1	2.4
2 kHz	0.1	2.5
4 kHz	0.8	1.2
8 kHz	0.3	1.3
16 kHz	0.0	0.9
STANDARD DEVIATIONS		
0.125 kHz	1.4	3.7
0.25 kHz	0.3	1.9
0.5 kHz	0.5	3.1
1 kHz	0.2	1.6
2 kHz	0.2	2.0
4 kHz	1.1	1.1
8 kHz	0.8	0.3
16 kHz	0.0	0.4

GROUP A: 100 IMPULSES @ 131 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K7R					
0.125 kHz	1.0	0.5	2.6	8.9	4.0
0.25 kHz	0.9	6.3	1.4	0.8	2.8
0.5 kHz	0.0	3.0	2.7	3.0	2.9
1 kHz	0.0	0.4	0.6	6.3	2.4
2 kHz	0.0	2.0	1.2	4.6	2.6
4 kHz	0.3	1.6	1.0	0.9	1.2
8 kHz	0.0	0.8	0.8	3.3	1.6
16 kHz	0.0	2.0	1.3	0.4	1.3
CHINCHILLA J35R					
0.125 kHz	0.6	2.5	22.3	15.6	13.5
0.25 kHz	0.3	1.7	4.0	6.3	4.0
0.5 kHz	0.3	0.2	2.4	1.4	1.3
1 kHz	0.0	3.6	3.8	5.7	4.4
2 kHz	0.0	4.7	5.6	6.8	5.7
4 kHz	0.3	1.6	0.0	1.0	0.9
8 kHz	0.0	2.0	0.2	0.7	1.0
16 kHz	0.0	0.8	1.3	0.6	0.9
CHINCHILLA K5R					
0.125 kHz	2.5	3.7	16.0	14.6	11.4
0.25 kHz	0.5	0.6	2.2	5.5	2.8
0.5 kHz	0.0	1.5	1.2	6.1	2.9
1 kHz	0.0	1.6	1.9	6.7	3.4
2 kHz	0.4	0.9	0.3	4.2	1.8
4 kHz	2.6	0.6	0.6	0.5	0.6
8 kHz	1.7	1.9	0.0	1.6	1.1
16 kHz	0.0	0.0	0.0	0.9	0.3

GROUP A: 100 IMPULSES @ 131 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA J34R					
0.125 kHz	3.3	3.5	6.1	26.5	12.0
0.25 kHz	0.3	1.2	0.5	5.6	2.4
0.5 kHz	1.1	0.5	3.8	1.4	1.9
1 kHz	0.3	0.3	2.4	0.4	1.0
2 kHz	0.0	2.1	1.8	1.7	1.9
4 kHz	0.3	2.6	4.4	1.7	2.9
8 kHz	0.0	0.9	1.2	0.9	1.0
16 kHz	0.0	1.3	0.9	0.3	0.8
CHINCHILLA K105R					
0.125 kHz	0.0	2.6	13.2	16.6	10.8
0.25 kHz	0.3	18.4	1.1	1.9	7.1
0.5 kHz	0.0	23.3	1.8	2.1	9.1
1 kHz	0.0	0.6	0.6	0.6	0.6
2 kHz	0.0	0.0	0.3	0.3	0.2
4 kHz	0.0	0.0	0.4	0.1	0.1
8 kHz	0.0	1.2	1.4	1.6	1.4
16 kHz	0.0	0.9	1.0	1.0	1.0

GROUP B: 100 IMPULSES @ 135 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	0.8	25.2
0.25 kHz	0.5	11.6
0.5 kHz	1.5	3.5
1 kHz	19.6	39.3
2 kHz	0.5	13.6
4 kHz	0.4	1.1
8 kHz	0.7	1.2
16 kHz	0.6	1.4
STANDARD DEVIATIONS		
0.125 kHz	1.0	31.8
0.25 kHz	0.8	14.4
0.5 kHz	1.5	2.1
1 kHz	28.1	39.0
2 kHz	0.6	19.1
4 kHz	0.3	0.6
8 kHz	1.0	0.7
16 kHz	0.6	1.3

GROUP B: 100 IMPULSES @ 135 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H184R					
0.125 kHz	0.0	1.4	1.9	6.1	3.2
0.25 kHz	0.3	1.5	1.8	3.6	2.3
0.5 kHz	0.7	2.2	2.0	2.4	2.2
1 kHz	1.5	9.2	12.7	7.7	9.9
2 kHz	1.2	1.2	2.5	1.8	1.8
4 kHz	0.0	0.9	0.0	0.6	0.5
8 kHz	2.2	0.3	1.6	1.2	1.0
16 kHz	1.6	1.0	0.8	0.3	0.7
CHINCHILLA K21R					
0.125 kHz	2.0	77.3	88.5	89.7	85.1
0.25 kHz	1.9	17.1	28.0	70.9	38.7
0.5 kHz	4.4	1.1	0.3	15.8	5.7
1 kHz	11.4	13.7	14.7	15.8	14.7
2 kHz	0.4	2.4	1.9	0.8	1.7
4 kHz	0.5	1.2	1.8	2.9	2.0
8 kHz	1.8	1.2	0.5	4.2	2.0
16 kHz	0.8	1.0	0.8	1.3	1.0
CHINCHILLA K108R					
0.125 kHz	0.0	0.0	1.6	10.9	4.2
0.25 kHz	0.0	0.0	0.3	2.9	1.0
0.5 kHz	1.1	1.2	1.8	2.2	1.7
1 kHz	1.7	87.7	88.1	78.8	84.9
2 kHz	1.3	44.9	44.9	31.8	40.5
4 kHz	0.0	0.6	0.4	0.3	0.4
8 kHz	0.4	0.0	0.8	0.3	0.4
16 kHz	0.0	1.4	0.0	0.0	0.4

GROUP B: 100 IMPULSES @ 135 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K103R					
0.125 kHz	0.6	3.6	16.4	31.1	17.0
0.25 kHz	0.3	4.4	3.9	13.2	7.1
0.5 kHz	0.3	8.3	6.4	4.4	6.4
1 kHz	71.8	95.2	95.8	78.7	89.9
2 kHz	0.0	42.8	57.0	7.2	35.7
4 kHz	0.7	0.6	3.1	1.1	1.6
8 kHz	0.0	1.2	3.7	1.2	2.0
16 kHz	0.6	2.9	5.0	3.7	3.8
CHINCHILLA K68R					
0.125 kHz	0.0	43.1	38.4	24.4	35.3
0.25 kHz	0.0	0.3	15.1	34.8	16.7
0.5 kHz	0.7	1.7	1.1	6.4	3.1
1 kHz	30.7	35.1	35.0	35.3	35.1
2 kHz	0.0	1.5	0.1	1.3	1.0
4 kHz	0.4	0.6	1.1	1.4	1.0
8 kHz	0.0	0.3	0.9	1.5	0.9
16 kHz	0.0	0.3	0.0	0.6	0.3
CHINCHILLA K116R					
0.125 kHz	2.0	2.6	5.1	11.3	6.3
0.25 kHz	0.0	0.8	0.3	9.1	3.4
0.5 kHz	1.2	0.9	1.5	2.8	1.7
1 kHz	0.0	0.7	0.4	1.4	0.9
2 kHz	0.0	0.7	0.4	0.3	0.5
4 kHz	0.8	0.9	0.3	0.9	0.7
8 kHz	0.0	0.9	0.6	0.0	0.5
16 kHz	0.4	1.7	0.6	2.4	1.6

GROUP C: 10 IMPULSES @ 139 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	0.7	14.0
0.25 kHz	0.6	2.6
0.5 kHz	0.4	2.3
1 kHz	0.3	1.7
2 kHz	0.5	1.8
4 kHz	0.2	0.8
8 kHz	2.8	3.8
16 kHz	0.1	0.8
STANDARD DEVIATIONS		
0.125 kHz	0.7	6.9
0.25 kHz	0.5	1.4
0.5 kHz	0.4	1.4
1 kHz	0.4	0.9
2 kHz	0.8	1.0
4 kHz	0.5	0.3
8 kHz	4.2	4.8
16 kHz	0.1	0.7

GROUP C: 10 IMPULSES @ 139 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA J10R					
0.125 kHz	0.6	8.7	17.0	18.7	14.8
0.25 kHz	1.1	1.3	1.4	3.4	2.0
0.5 kHz	0.4	3.3	2.6	1.2	2.3
1 kHz	0.0	1.5	2.9	3.3	2.6
2 kHz	0.0	7.4	2.4	0.4	3.4
4 kHz	0.0	0.9	1.2	0.9	1.0
8 kHz	0.0	0.7	0.6	0.0	0.4
16 kHz	0.0	1.6	2.4	1.7	1.9
CHINCHILLA J18R					
0.125 kHz	0.6	15.6	23.7	39.7	26.3
0.25 kHz	0.7	0.2	0.4	4.7	1.8
0.5 kHz	0.7	1.1	0.8	1.7	1.2
1 kHz	0.0	0.6	0.0	0.3	0.3
2 kHz	0.0	0.6	0.4	0.6	0.5
4 kHz	0.0	1.5	0.1	0.3	0.6
8 kHz	0.0	1.2	0.0	0.3	0.5
16 kHz	0.0	0.0	0.0	1.0	0.3
CHINCHILLA J8R					
0.125 kHz	0.6	1.0	6.6	13.9	7.1
0.25 kHz	0.7	0.5	0.4	3.0	1.3
0.5 kHz	0.7	3.8	6.3	4.6	4.9
1 kHz	0.0	0.9	1.2	6.5	2.9
2 kHz	0.0	0.9	0.0	2.0	0.9
4 kHz	1.1	0.3	0.0	0.3	0.2
8 kHz	7.1	10.8	11.4	11.1	11.1
16 kHz	0.0	0.0	0.0	0.0	0.0

GROUP C: 10 IMPULSES @ 139 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA J23BR					
0.125 kHz	0.0	3.5	8.6	12.7	8.3
0.25 kHz	0.0	1.0	1.2	7.2	3.1
0.5 kHz	0.4	0.3	2.2	5.8	2.8
1 kHz	0.8	0.9	2.5	3.3	2.2
2 kHz	0.4	0.9	0.9	2.8	1.5
4 kHz	0.0	1.5	0.0	0.5	0.7
8 kHz	9.0	9.2	8.6	8.0	8.6
16 kHz	0.0	0.0	0.0	1.7	0.5
CHINCHILLA J17R					
0.125 kHz	0.0	3.5	13.5	20.6	12.5
0.25 kHz	0.0	1.4	2.5	2.5	2.1
0.5 kHz	0.0	0.5	0.7	2.2	1.2
1 kHz	0.7	1.3	0.9	1.7	1.3
2 kHz	0.3	2.0	1.2	2.3	1.8
4 kHz	0.0	0.4	2.0	0.6	1.0
8 kHz	0.3	0.0	0.8	0.8	0.5
16 kHz	0.0	0.0	0.9	0.3	0.4
CHINCHILLA J18BR					
0.125 kHz	1.8	2.2	10.6	31.4	14.7
0.25 kHz	0.5	3.4	1.2	10.7	5.1
0.5 kHz	0.0	1.0	3.2	1.4	1.9
1 kHz	0.0	2.1	4.4	0.9	2.5
2 kHz	2.1	2.9	2.0	1.4	2.1
4 kHz	0.0	1.3	1.5	0.0	0.9
8 kHz	0.0	1.5	1.5	0.3	1.1
16 kHz	0.3	2.1	1.0	0.7	1.2

GROUP D: 100 IMPULSES @ 139 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	1.5	21.6
0.25 kHz	1.2	5.9
0.5 kHz	1.6	35.9
1 kHz	16.0	80.8
2 kHz	11.5	60.5
4 kHz	4.4	18.4
8 kHz	3.2	7.0
16 kHz	0.4	2.3
STANDARD DEVIATIONS		
0.125 kHz	1.5	19.4
0.25 kHz	1.2	2.9
0.5 kHz	1.6	23.3
1 kHz	14.9	15.1
2 kHz	14.0	35.6
4 kHz	6.9	20.8
8 kHz	4.4	10.6
16 kHz	0.4	3.9

GROUP D: 100 IMPULSES @ 139 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

CHINCHILLA E109R

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	0.3	1.6	8.8	25.9	12.1
0.25 kHz	2.2	1.2	3.6	13.9	6.2
0.5 kHz	1.0	47.6	44.9	31.5	41.3
1 kHz	30.4	85.3	84.0	70.3	79.9
2 kHz	1.3	1.9	10.6	3.1	5.2
4 kHz	1.7	1.5	1.2	2.2	1.7
8 kHz	3.0	5.5	6.1	5.1	5.6
16 kHz	0.0	0.0	0.3	0.3	0.2

CHINCHILLA G30R

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	3.3	17.5	31.6	32.4	27.2
0.25 kHz	0.6	10.8	5.6	9.8	8.7
0.5 kHz	2.0	71.6	60.6	53.0	61.7
1 kHz	37.3	99.6	99.6	97.2	98.8
2 kHz	35.0	100.0	100.0	95.7	98.5
4 kHz	18.3	57.5	62.1	56.4	58.6
8 kHz	0.0	0.6	0.3	0.6	0.5
16 kHz	0.4	0.0	0.0	0.6	0.2

CHINCHILLA E144R

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	1.0	2.6	7.7	20.8	10.4
0.25 kHz	1.0	3.2	1.5	7.0	3.9
0.5 kHz	0.0	36.0	20.3	13.0	23.1
1 kHz	0.0	96.7	77.2	32.3	68.8
2 kHz	0.0	82.9	79.3	21.8	61.3
4 kHz	1.1	15.2	12.8	12.1	13.4
8 kHz	11.9	21.9	20.5	42.7	28.4
16 kHz	0.0	3.9	4.6	22.2	10.2

GROUP D: 100 IMPULSES @ 139 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H16R					
0.125 kHz	0.6	54.7	65.0	56.8	58.8
0.25 kHz	1.1	8.0	2.6	17.7	9.4
0.5 kHz	2.4	77.3	68.3	41.7	62.4
1 kHz	3.2	100.0	99.6	86.4	95.3
2 kHz	0.8	47.9	70.8	13.5	44.1
4 kHz	0.8	4.3	4.6	5.0	4.6
8 kHz	0.3	0.6	3.6	4.0	2.7
16 kHz	0.0	1.3	0.8	2.7	1.6
CHINCHILLA H1R					
0.125 kHz	3.3	6.5	10.5	12.5	9.9
0.25 kHz	0.7	4.7	4.4	5.5	4.9
0.5 kHz	2.4	9.3	3.4	3.4	5.4
1 kHz	11.5	82.7	61.6	34.3	59.5
2 kHz	11.3	51.9	51.9	59.2	54.3
4 kHz	1.0	1.4	1.6	31.7	11.5
8 kHz	1.5	1.1	0.8	5.2	2.4
16 kHz	1.6	0.3	0.6	0.3	0.4
CHINCHILLA H42R					
0.125 kHz	0.0	7.5	16.0	10.0	11.2
0.25 kHz	1.1	0.5	2.0	3.3	1.9
0.5 kHz	1.5	19.6	14.1	29.0	20.9
1 kHz	13.3	94.3	78.1	74.5	82.3
2 kHz	20.4	99.9	99.9	98.8	99.6
4 kHz	3.5	25.2	24.6	11.6	20.5
8 kHz	2.1	2.9	1.7	2.0	2.2
16 kHz	0.4	0.9	1.3	0.3	0.8

GROUP E: 1 IMPULSE @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	0.5	16.4
0.25 kHz	0.1	3.2
0.5 kHz	0.3	3.2
1 kHz	0.6	2.2
2 kHz	0.2	1.1
4 kHz	0.6	0.8
8 kHz	0.2	0.5
16 kHz	0.9	5.8
STANDARD DEVIATIONS		
0.125 kHz	0.8	11.5
0.25 kHz	0.2	1.4
0.5 kHz	0.4	2.6
1 kHz	0.2	1.7
2 kHz	0.2	0.6
4 kHz	0.7	0.6
8 kHz	0.3	0.3
16 kHz	2.2	13.7

GROUP E: 1 IMPULSE @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA X15R					
0.125 kHz	0.0	3.5	8.7	10.8	7.7
0.25 kHz	0.4	2.2	1.8	2.1	2.0
0.5 kHz	0.0	5.4	2.2	2.0	3.2
1 kHz	0.3	3.3	1.6	3.7	2.9
2 kHz	0.0	2.4	1.2	1.6	1.7
4 kHz	0.3	0.9	1.5	1.6	1.3
8 kHz	0.0	1.8	0.3	0.0	0.7
16 kHz	0.0	0.0	0.0	0.0	0.0
CHINCHILLA J13R					
0.125 kHz	1.4	24.9	43.5	37.2	35.2
0.25 kHz	0.3	1.2	4.0	8.5	4.6
0.5 kHz	0.7	1.0	1.6	2.7	1.7
1 kHz	0.4	1.2	0.6	1.2	1.0
2 kHz	0.0	0.6	0.6	0.9	0.7
4 kHz	0.7	0.3	0.9	0.6	0.6
8 kHz	0.7	0.9	0.3	0.0	0.4
16 kHz	0.0	0.0	0.0	0.0	0.0
CHINCHILLA J15R					
0.125 kHz	1.6	6.7	8.7	15.3	10.2
0.25 kHz	0.0	0.7	0.0	2.1	0.9
0.5 kHz	0.0	1.7	1.4	2.3	1.8
1 kHz	0.9	0.0	0.3	0.3	0.2
2 kHz	0.4	1.1	0.0	0.3	0.4
4 kHz	0.4	0.3	0.0	0.0	0.1
8 kHz	0.0	0.7	0.3	1.1	0.7
16 kHz	0.0	1.2	0.0	0.4	0.5

GROUP E: 1 IMPULSE @ 147 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA J21R					
0.125 kHz	0.0	13.1	24.1	20.3	19.2
0.25 kHz	0.0	2.4	1.5	7.1	3.7
0.5 kHz	0.0	0.6	1.6	1.2	1.1
1 kHz	0.4	0.0	1.2	2.3	1.1
2 kHz	0.0	0.6	0.6	1.2	0.8
4 kHz	2.0	1.2	0.6	0.0	0.6
8 kHz	0.0	0.0	0.0	0.3	0.1
16 kHz	0.0	0.0	0.0	0.0	0.0
CHINCHILLA J14AR					
0.125 kHz	0.0	12.0	29.1	24.1	21.7
0.25 kHz	0.0	7.2	3.2	2.2	4.2
0.5 kHz	0.7	3.9	13.9	6.9	8.2
1 kHz	0.7	2.3	8.1	4.1	4.8
2 kHz	0.3	2.8	1.4	1.0	1.7
4 kHz	0.0	0.0	0.3	0.8	0.4
8 kHz	0.0	0.0	0.2	0.5	0.2
16 kHz	5.3	29.6	32.9	38.5	33.7
CHINCHILLA J20AR					
0.125 kHz	0.0	1.1	3.0	7.5	3.9
0.25 kHz	0.0	1.8	0.8	7.0	3.2
0.5 kHz	0.0	0.9	5.0	1.5	2.5
1 kHz	0.4	2.3	3.1	4.0	3.1
2 kHz	0.0	1.6	0.6	0.4	0.9
4 kHz	0.0	2.7	1.3	1.2	1.7
8 kHz	0.4	0.8	0.3	0.5	0.5
16 kHz	0.0	0.0	0.7	1.0	0.6

GROUP F: 10 IMPULSES @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	0.5	10.8
0.25 kHz	6.7	6.3
0.5 kHz	13.3	29.4
1 kHz	31.9	49.5
2 kHz	12.6	45.9
4 kHz	18.3	36.5
8 kHz	8.3	32.4
16 kHz	0.7	13.0
STANDARD DEVIATIONS		
0.125 kHz	0.6	4.4
0.25 kHz	14.1	6.8
0.5 kHz	18.3	30.4
1 kHz	42.1	49.8
2 kHz	20.4	48.4
4 kHz	23.8	48.3
8 kHz	13.4	46.2
16 kHz	1.1	21.8

GROUP F: 10 IMPULSES @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA X4R					
0.125 kHz	0.7	4.3	6.5	13.0	7.9
0.25 kHz	0.8	30.3	18.0	10.8	19.7
0.5 kHz	7.7	85.3	84.1	40.2	69.9
1 kHz	94.6	100.0	99.6	98.4	99.3
2 kHz	23.6	99.9	99.9	99.6	99.8
4 kHz	46.8	100.0	100.0	100.0	100.0
8 kHz	32.2	79.4	83.5	99.0	87.3
16 kHz	0.9	13.0	20.1	21.3	18.1
CHINCHILLA J9R					
0.125 kHz	0.1	0.5	3.5	11.7	5.3
0.25 kHz	35.3	3.3	2.4	2.1	2.6
0.5 kHz	23.8	3.9	2.1	5.6	3.9
1 kHz	5.3	3.6	1.5	9.1	4.7
2 kHz	0.0	3.4	3.8	4.9	4.0
4 kHz	1.7	2.4	0.6	1.7	1.6
8 kHz	0.0	0.0	0.5	0.6	0.4
16 kHz	0.0	1.9	0.5	0.3	0.9
CHINCHILLA X3R					
0.125 kHz	1.3	3.6	8.8	11.8	8.1
0.25 kHz	3.5	10.3	2.9	4.2	5.8
0.5 kHz	45.9	81.9	64.5	33.7	60.0
1 kHz	75.7	100.0	99.6	94.9	98.1
2 kHz	49.5	100.0	100.0	100.0	100.0
4 kHz	50.5	99.3	98.5	92.7	96.8
8 kHz	16.5	95.9	97.2	95.1	96.1
16 kHz	2.8	52.1	58.2	55.0	55.1

GROUP F: 10 IMPULSES @ 147 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA J1R					
0.125 kHz	0.0	8.3	18.2	24.1	16.8
0.25 kHz	0.3	2.7	3.4	9.0	5.0
0.5 kHz	0.8	50.2	39.5	18.0	35.9
1 kHz	15.1	99.6	95.6	64.9	86.7
2 kHz	1.6	81.3	74.5	40.7	65.5
4 kHz	1.2	2.8	2.4	2.7	2.7
8 kHz	0.0	1.7	0.0	2.3	1.3
16 kHz	0.0	0.7	0.3	1.1	0.7
CHINCHILLA J4R					
0.125 kHz	0.0	5.5	14.5	22.6	14.2
0.25 kHz	0.0	1.9	1.0	3.8	2.2
0.5 kHz	0.4	0.9	7.2	3.0	3.7
1 kHz	0.0	1.2	5.0	7.3	4.5
2 kHz	0.4	1.2	2.1	5.8	3.0
4 kHz	0.4	0.3	2.8	4.6	2.6
8 kHz	0.6	0.4	0.2	0.3	0.3
16 kHz	0.1	0.2	0.0	0.3	0.1
CHINCHILLA G29R					
0.125 kHz	0.7	2.7	7.1	26.1	12.0
0.25 kHz	0.0	1.3	1.2	3.6	2.0
0.5 kHz	1.2	4.9	2.2	1.8	2.9
1 kHz	0.4	4.7	4.6	1.0	3.4
2 kHz	0.0	2.5	2.5	2.2	2.4
4 kHz	8.8	14.8	14.8	14.8	14.8
8 kHz	0.4	8.6	9.0	8.3	8.7
16 kHz	0.0	2.5	2.8	2.5	2.6

GROUP G: 100 IMPULSES @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	5.9	14.3
0.25 kHz	6.7	27.2
0.5 kHz	21.7	60.4
1 kHz	41.0	91.8
2 kHz	42.6	99.5
4 kHz	37.6	99.5
8 kHz	45.3	83.7
16 kHz	36.4	67.4
STANDARD DEVIATIONS		
0.125 kHz	8.6	8.4
0.25 kHz	7.4	21.6
0.5 kHz	15.8	26.3
1 kHz	36.7	8.6
2 kHz	35.4	0.7
4 kHz	28.7	1.2
8 kHz	33.6	32.6
16 kHz	37.8	50.5

GROUP G: 100 IMPULSES @ 147 dB

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E115R					
0.125 kHz	7.3	5.9	3.6	11.2	6.9
0.25 kHz	2.6	8.9	3.7	3.4	5.3
0.5 kHz	30.4	64.0	58.2	12.0	44.7
1 kHz	33.5	98.6	91.5	43.1	77.7
2 kHz	65.3	99.9	99.9	98.3	99.4
4 kHz	45.6	100.0	100.0	99.8	99.9
8 kHz	79.5	100.0	100.0	100.0	100.0
16 kHz	79.2	99.9	99.9	99.9	99.9
CHINCHILLA F1R					
0.125 kHz	0.0	7.4	11.0	14.6	11.0
0.25 kHz	2.8	0.5	0.7	4.9	2.0
0.5 kHz	20.9	31.8	26.2	17.7	25.2
1 kHz	69.0	95.5	89.3	78.9	87.9
2 kHz	47.8	99.9	99.9	99.9	99.9
4 kHz	59.0	100.0	100.0	100.0	100.0
8 kHz	36.2	78.5	83.8	88.4	83.6
16 kHz	0.5	1.4	2.8	3.3	2.5
CHINCHILLA E138R					
0.125 kHz	3.4	21.4	21.3	37.7	26.8
0.25 kHz	1.5	66.1	38.0	38.4	47.5
0.5 kHz	3.5	99.7	95.9	89.6	95.1
1 kHz	48.4	100.0	99.8	99.3	99.7
2 kHz	11.5	99.9	99.9	99.9	99.9
4 kHz	10.8	100.0	100.0	100.0	100.0
8 kHz	19.9	100.0	100.0	100.0	100.0
16 kHz	4.6	99.9	99.9	99.9	99.9

GROUP G: 100 IMPULSES @ 147 dB cont.

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1st ROW OUTER HAIR CELLS	2nd ROW OUTER HAIR CELLS	3rd ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA G2R					
0.125 kHz	1.3	21.1	20.1	17.5	19.6
0.25 kHz	17.3	80.7	37.5	14.7	44.3
0.5 kHz	24.9	83.6	69.7	29.2	60.8
1 kHz	0.9	99.0	97.2	69.4	88.5
2 kHz	12.8	100.0	100.0	94.3	98.1
4 kHz	6.5	99.5	98.7	93.0	97.0
8 kHz	0.7	30.3	17.0	8.2	18.5
16 kHz	2.0	3.9	0.8	1.0	1.9
CHINCHILLA G20R					
0.125 kHz	22.6	2.0	2.3	9.4	4.6
0.25 kHz	14.7	48.4	39.9	53.8	47.4
0.5 kHz	45.3	98.8	86.8	73.1	86.2
1 kHz	92.4	99.8	100.0	100.0	99.9
2 kHz	99.9	99.9	99.9	99.9	99.9
4 kHz	79.3	100.0	100.0	100.0	100.0
8 kHz	48.0	100.0	100.0	100.0	100.0
16 kHz	59.0	100.0	100.0	100.0	100.0
CHINCHILLA G5R					
0.125 kHz	0.6	12.2	18.8	19.7	16.9
0.25 kHz	0.7	22.9	13.3	13.8	16.7
0.5 kHz	5.2	78.3	40.0	31.7	50.0
1 kHz	1.2	99.6	96.1	93.6	96.4
2 kHz	18.1	100.0	100.0	97.8	99.2
4 kHz	23.9	99.9	99.9	99.6	99.8
8 kHz	87.1	99.9	99.9	99.9	99.9
16 kHz	72.7	100.0	100.0	100.0	100.0

APPENDIX E

FORMULA FOR COMPUTATION OF ENERGY LEVELS OF THE IMPULSE EXPOSURE*

The following equation was used to calculate the energy transported with an impulse per unit of area.

$$W = \frac{1}{\rho c} \int_{-\infty}^{\infty} p^2(t)\, dt \qquad (1)$$

The following definitions apply:

W is energy per unit area transported in the specified direction (joules/ M^2.)

P(t) is the instantaneous pressure as a function of time (Pa)

ρc is the specific acoustic impedance taken as 410 rayls (N.Sec/M^3) for air

This equation is subject to the assumption that the impulse measured in the far field is a plane wave. It should be noted that the pressure measurements were made without the animal in position but at a point in space approximating the entrance to the animal's ear canal during the exposures. Equation (1) then was approximated by digital integration of a tine series representing P(t) for a single impulse. This value was then converted to a level by

$$L_E = 10 \log W/W_o \qquad (2)$$

where W_o was taken to be 1 joule/M^2. The exposure energy (EE) level for each experimental condition was then calculated by

$$EE = L_E + 10 \log N \qquad (3)$$

Where N is the number of impulses in the exposure.

* Young, R.W., 1970. On the energy transported with a sound pulse. *Journal of the Acoustical Society of America*. 47, pp441-442.

APPENDIX F

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